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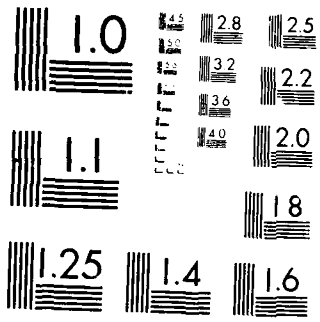

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Junction Code User's Manual

Electromagnetic Scattering and Radiation by Arbitrary Configurations of Conducting Bodies and Wires

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Chapter 1

Introduction

1.1 JUNCTION Code

This report gives a brief description of the computer program JUNCTION which results from the application of numerical procedures ~~described in~~ [1]. The program invokes the method of moments to solve a coupled electric field integral equation for the currents induced on an arbitrary configuration of perfectly conducting bodies and wires. An important feature of the code is its ability to treat wire-to-wire, surface-to-surface, and wire-to-surface junctions. Wires may be connected to surfaces at essentially arbitrary angles and may be attached to surface edges or vertices. Results obtained using this algorithm are in the form of electric current and charge densities and far field patterns.

Fig.1.1 depicts a typical conducting wire and body configuration which might be treated by JUNCTION. The theory leading to a numerical algorithm for treating such structures is described in [1]. Here we are mostly concerned with describing the format of the input data for specifying the problem geometry and excitation to JUNCTION. This data may be generated by any number of means by using an outboard program specially written for a given geometry, by running an interactive geometry generation program such as IGUANA[2], or by entering data via a digitizing tablet. JUNCTION only requires that two input files exist which contain the following problem specifications:

1. Planar triangular patch model of surfaces . A completely specified surface model merely consists of a collection of numbered *vertices* (corners of the triangular patches) and their coordinates, and an *edge connection list* specifying which pair of vertices each numbered edge connects.

2. Piecewise linear segment model of wires. A completely specified wire model merely consists of a collection of numbered *nodes* and their coordinates, and a *segment connection list* specifying

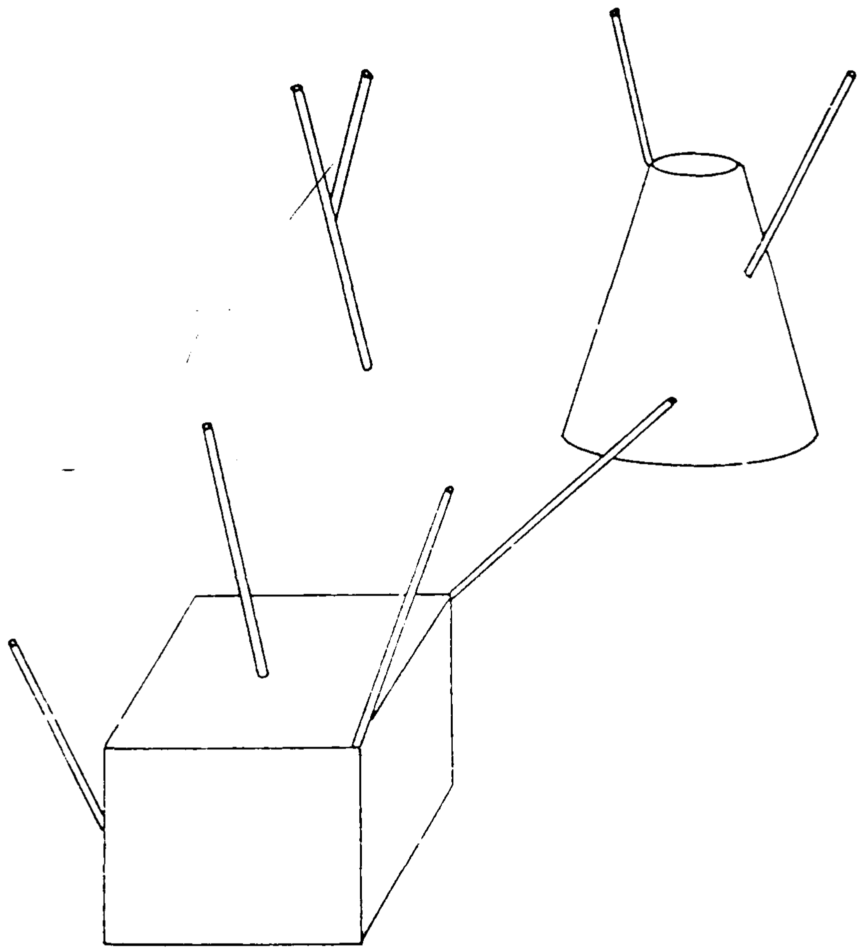

Figure 1.1: Typical conducting wire and body configuration.

which pair of nodes each numbered segment connects.

3. Excitation information such as frequency, angle of arrival, and polarization of incident plane waves, and location and magnitudes of voltage sources.

4. Ground plane and/or symmetry information requiring the specification locations and types of image planes.

5. Output control parameters.

A detailed description of the format of the input data may be found in Section 2.3.

1.2 Program Structure

Figs. 1.2-1.5 illustrates in block diagram form the dependence of the subroutines on their calling routines in JUNCTION. The figures group the subroutines roughly according to their function. For example, Fig. 1.2 shows the subroutines called by the main controller program, JUNCTION. The subroutines shown in Fig. 1.3 are all called by the input data generation subroutine, DATGEN. Subroutines shown in Fig. 1.4 are called by the subroutine SOLTN, which controls the matrix element computation and matrix solving processes. The main task in the matrix element computation step is the computation of potential integrals. This task is controlled by the subroutines POTBOD and POTWIR shown in Fig. 1.5. Listings for all subroutines in JUNCTION except CGESL and CGEFA (called by SOLTN) may be found in Appendix A. These latter two subroutines are contained in the LINPACK library [5] and may be replaced by any linear equation solving package if desired.

Fig. 1.6 shows the relationship between JUNCTION and the software package NEEDS (Numerical Electromagnetics Engineering Design System). It should be understood that JUNCTION is a stand-alone program, but that translators have been added to it to allow it to interface with NEEDS. Thus JUNCTION can read a file formatted in NEC (Numerical Electromagnetic Code) [3] format and generated by NEEDS. It can also translate JUNCTION formatted data to NEC formatted data for convenient display using the IGUANA (Interactive Graphics Utility for Automated NEC Analysis) software contained in NEEDS.

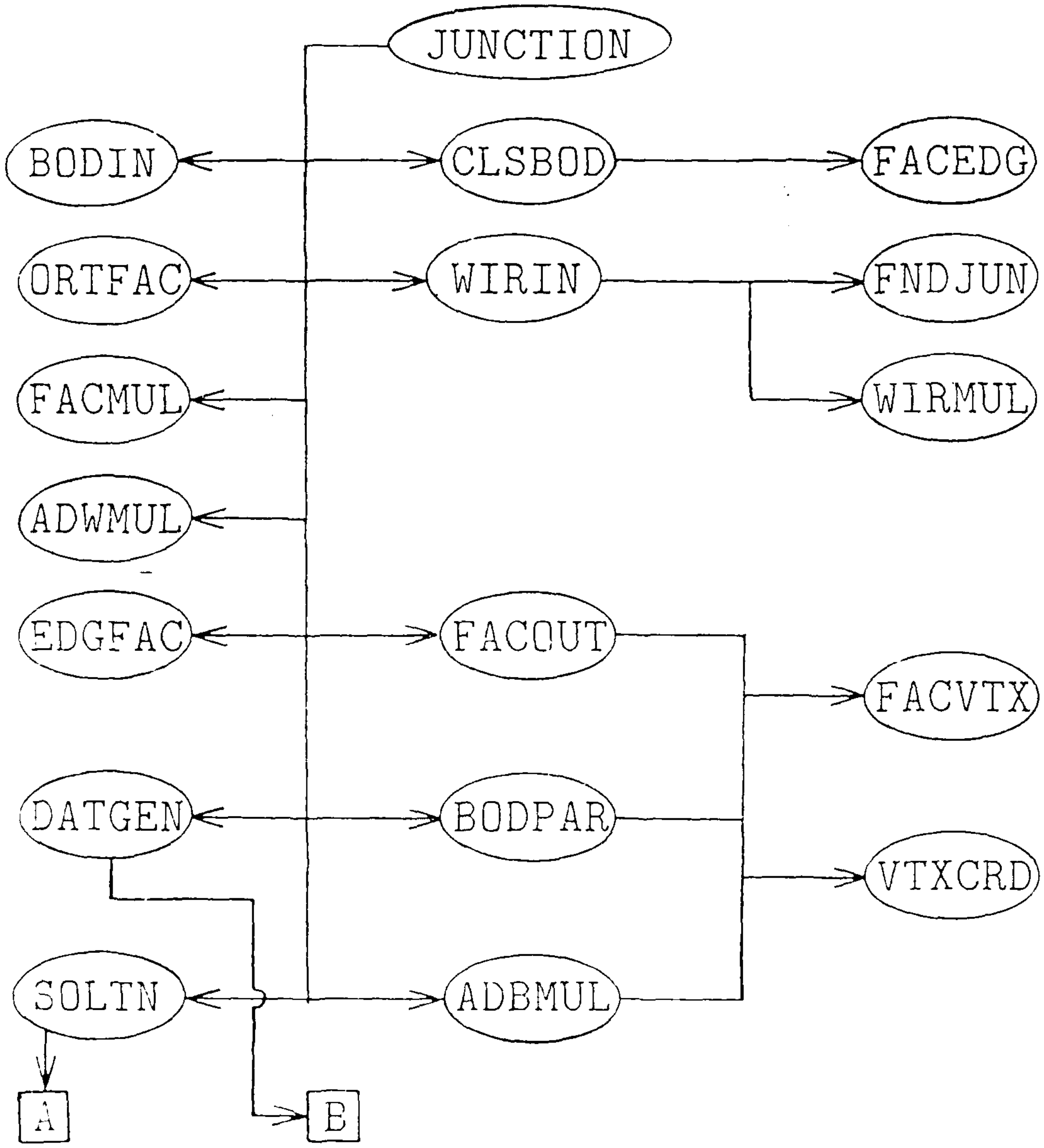

Figure 1.2: Structure of controlling program JUNCTION.

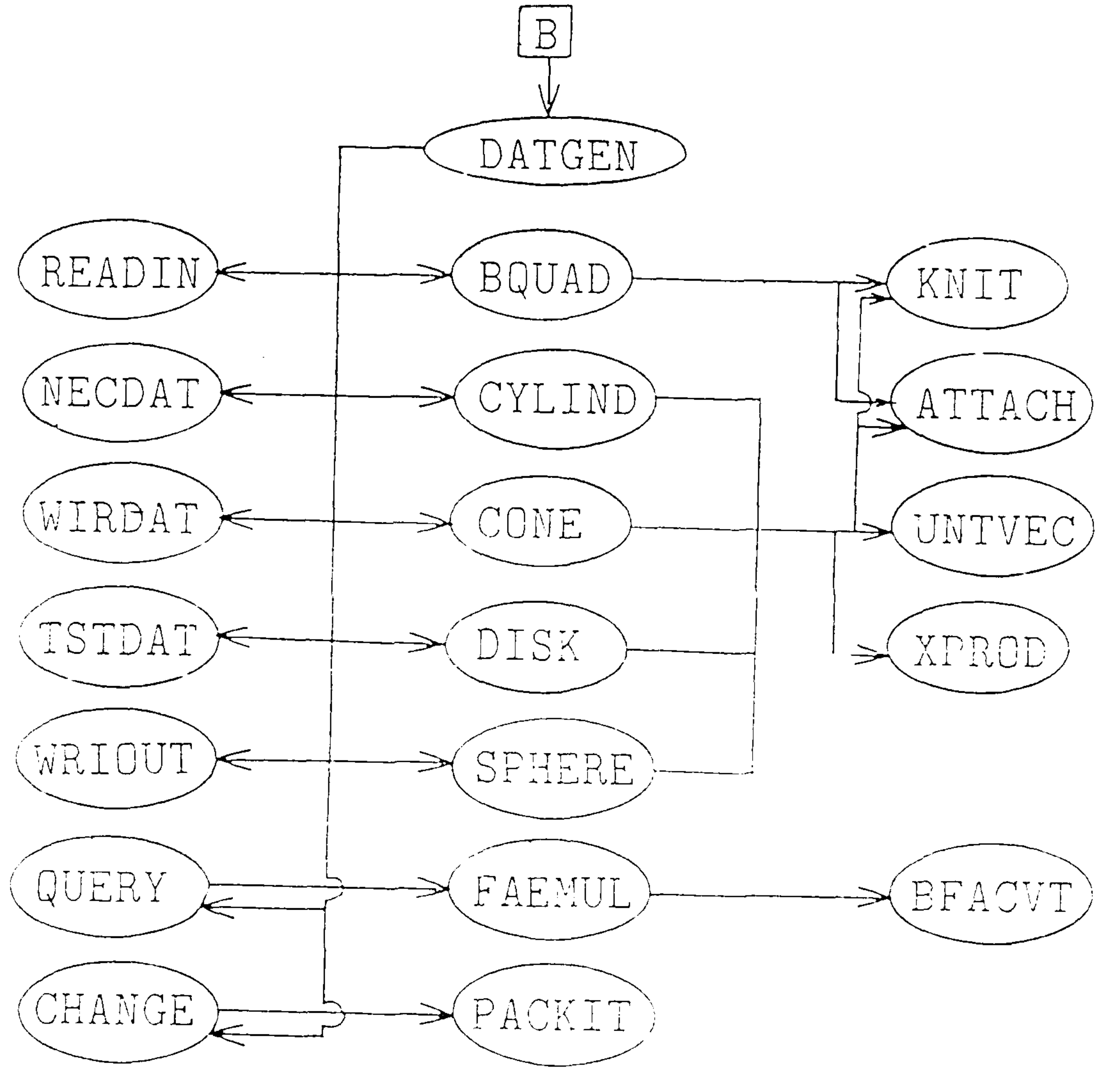

Figure 1.3: Subroutines called by DATGEN.

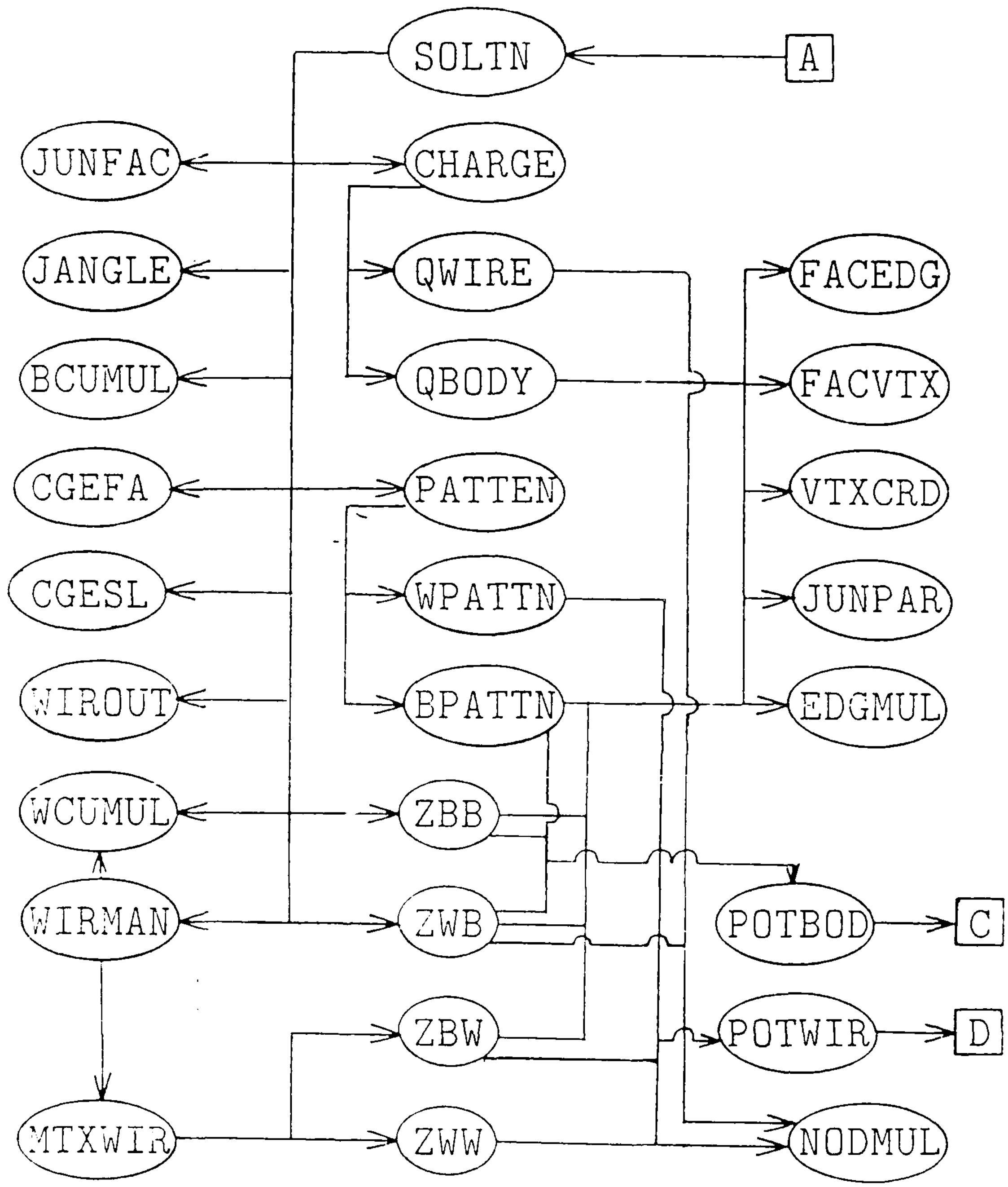

Figure 1.4: Subroutines called by SOLTN.

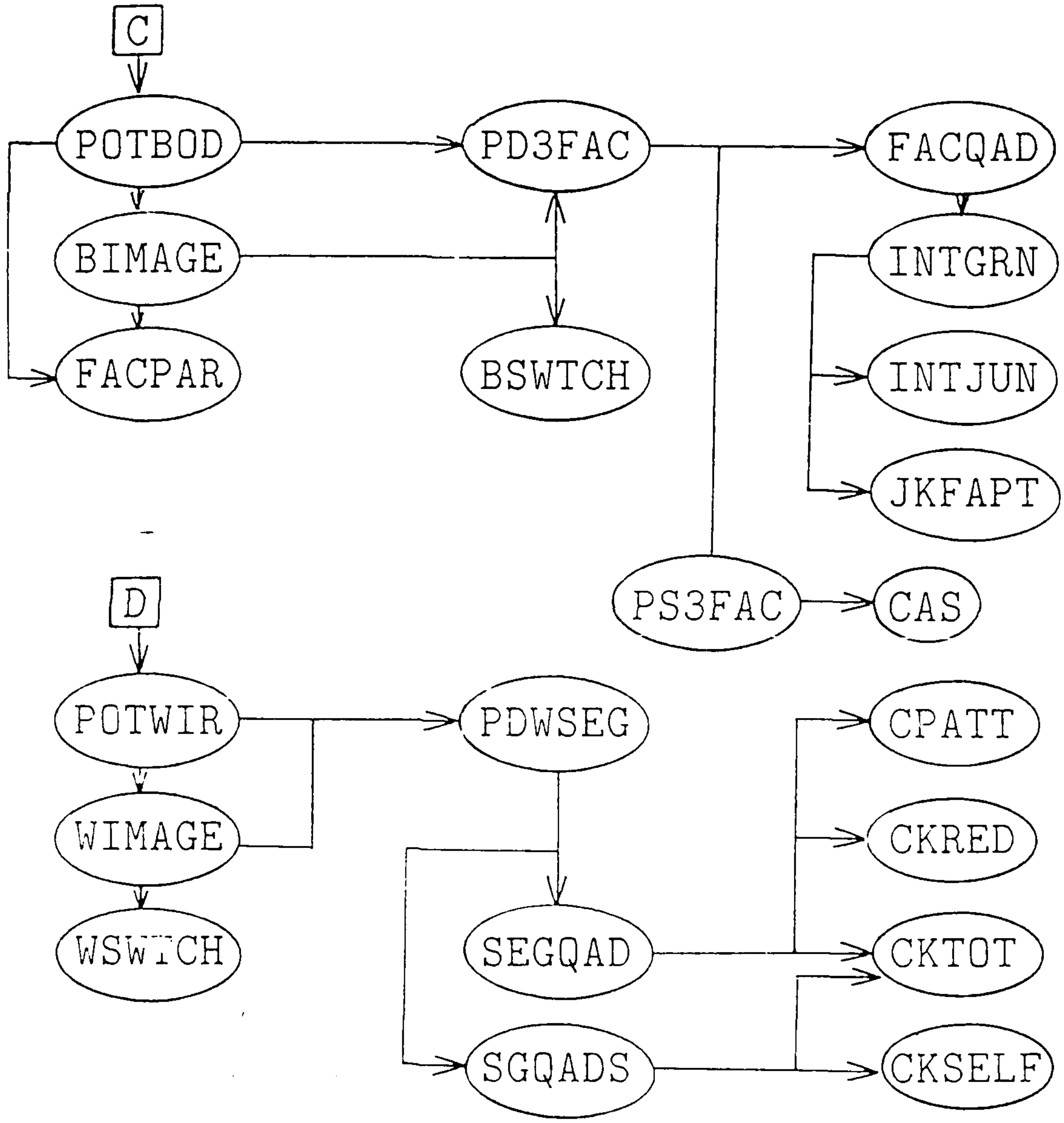

Figure 1.5: Subroutines called by POTBOD and POTWIR.

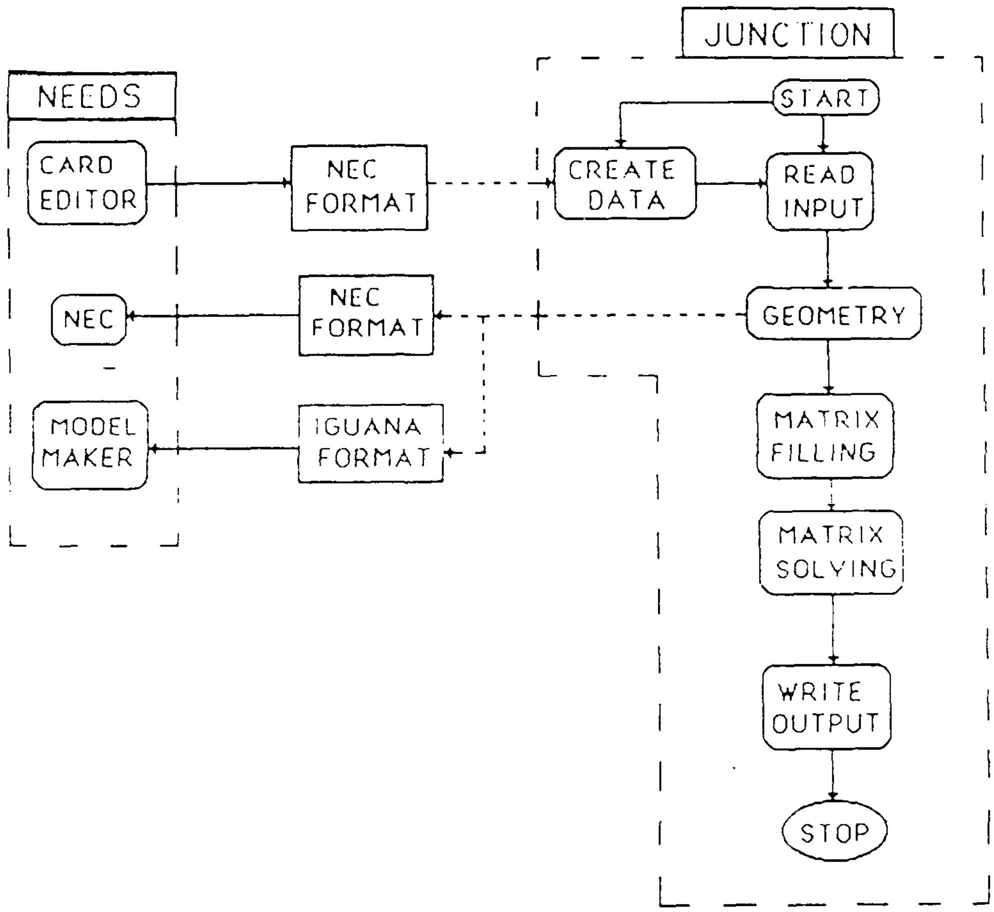

Figure 1.6: Block diagram depicting relationships between JUNCTION and NEEDS.

Chapter 2

Data Generation

In the following sections we discuss several practical aspects related to modeling a structure and to using the JUNCTION code. User aspects include generation of the geometry, and specification of input parameters.

2.1 Triangular Patch and Wire Modeling

The first step in the numerical solution of any practical electromagnetics problem is to accurately model the geometry and to represent it in some form which can be easily handled by the computer. In JUNCTION, we wish to model surfaces and wires by means of discrete triangular patches and segments, respectively. Triangulation and segmentation schemes are non-unique, and finding a suitable one may at first appear to require a certain amount of experience or intuition. However, there are several guidelines which can be followed in order to effectively model a structure. The cardinal rule, however, is simply this—*the density of the triangulation or segmentation should be sufficient to model both the local variations in the surface or wire geometry and in the surface current density.*

2.2 Automatic Triangulation and Segmentation of Models

The generation of the geometry for input to JUNCTION is often greatly simplified by using a geometry preprocessing program called DATGEN. This program is an extension of the program BUILD developed at Sandia laboratories [4] and has been incorporated into JUNCTION. This menu-driven subprogram allows the user to build up a collection of arbitrary bodies by joining together certain canonical three-dimensional triangulated shapes (primitives) to form objects. The

extension contained in JUNCTION also allows the user to add segmented linear wires to form composite wire-and-conducting-body problem geometries. All surface and wire intersections which form junctions are automatically found by JUNCTION by comparing vertex and node coordinates.

DATGEN is an interactive program which is called by JUNCTION and which prompts the user to choose from its catalog of canonical surface shapes or to edit existing geometry files. In creating bodies or wires, the user also provides information to allow DATGEN to automatically subdivide these geometrical elements into triangular patches or segments as required by JUNCTION's input data file. The options available in DATGEN's geometry menu and the required input necessary to define each shape is listed below:

1. **NEC Data**—Input data files are formed by translating a NEC formatted data file which includes GW, SP and SC geometry cards.

2. **Quadrilateral**—A quadrilateral is formed by specifying the coordinates for the four corners in order of progression around the boundary, then specifying the number of edges desired along the side formed by the first two corners, and the number of edges desired along an adjacent side.

3. **Cylinder**—A cylinder is formed by first specifying the center points of the two end plates of the cylinder. Next a point on the circumference of each end plate is defined. These points need not be equidistant from the center points; if they are not, a section of a conical surface is formed. Either end of the cylinder may be open or closed. The number of edges around the circumference of the cylinder, along its axis, and radially along the endcaps (if present) are also specified. A slotted cylinder may also be generated by specifying a beginning and ending angle at each end plate. If the points specified on the end plates are rotated about the axis with respect to one another, then the triangulation scheme and the slot, if present, is similarly twisted about the cylindrical surface.

4. **Cone**—An open-ended, finite-length cone is defined by first specifying the coordinates of the apex. Next, the coordinates of points at the center and on the circumference of the base are given. Finally, the number of edges around the circumference and the number of edges from the apex to the base are specified.

5. **Disk**—A disk is generated by specifying the coordinates of a point at the center, a point on the circumference, and a point on a line perpendicular to and passing through the center of the disk. The triangulation scheme is specified by entering the number of circumferential and radial edges.

6. **Sphere**—The sphere is specified by entering three points: a point at the center, a point at the north pole, and a point on the equator corresponding to zero degrees longitude. It is possible to specify only a sector of a spherical surface. The beginning and ending angles of

the longitudes and latitudes of the sector boundaries are specified, followed by the number of edges along the corresponding directions.

7. **Wire**—A straight wire is formed by specifying the coordinates of the two ends, then specifying the number of subsegments desired and the radius of the wire.

The above geometries are automatically joined by DATGEN along any completely coincident edges by eliminating redundant edges and vertices from the model. The output of DATGEN consists of matrices characterizing the model wire and surface geometries plus a list of so-called "test parameters" which specify the excitation, symmetries present, and quantities to be computed by JUNCTION. The test data are generated from interactive input and are required input for JUNCTION. The geometry data for bodies (wires) consists of two set of matrices. The first matrix is a vertex (node) list matrix in which the row index corresponds to a vertex (node) number and the associated elements are its three-dimensional coordinates with respect to a global origin. The second matrix is an edge (segment) matrix in which the row index corresponds to an edge (a segment) number and the associated elements are the numbers of the two vertices (nodes) to which it is connected.

2.3 Specification of Input Data

Table 2.1 and 2.2 provide the format of and a brief description of the input data files required by JUNCTION. These files can either be generated by the user, or generated interactively through DATGEN. The following notes apply to Tables 2.1 and 2.2 and more fully explain the function of each parameter in the two input data files.

Notes on Tables 2.1 and 2.2:

1. NJCT specifies the type of wire/body configuration. A value of -1 indicates that a conducting body is present, but no wires; 1 indicates there are bodies, wires and wire-to-surface junctions; 0 indicates there are bodies and wires but no wire-to-surface junctions present in this geometry configuration.

2. The *number of ground planes*, NGNDP, specifies the number of image planes (electric or magnetic) to be used on symmetrical structures. If this parameter is non-zero, a value must be given for the type of image plane at $x = 0, y = 0, z = 0$ in the IGNDP parameter line. If NGNDP is zero, then zero can be specified for each of the image planes.

3. IGNDP specifies the type of image plane to be placed in the $x = 0$, $y = 0$, and $z = 0$ planes, respectively. A value of -1 indicates a perfect magnetic conductor , a $+1$ indicates a perfect electric conductor, and a 0 indicates no image plane present.

Table 2.1: DESCRIPTION OF INPUT DATA IN FOR002.DAT

NJCT MNJUN	Junction flag, number of junctions.
NNODES NEDGES	Number of nodes, edges.
NODE X Y Z	Vertex number and rectangular coordinates.
⋮	
NE NF NT	Edge number, "from" node and "to" node.
⋮	
NGNDP	Number of ground planes.
IGNDP(1) IGNDP(2) IGNDP(3)	Ground plane type for $x = 0, y = 0, z = 0$.
IPAT	Pattern flag.
THETA1 THETA2 NTHETA PHI1 PHI2 NPHI	Start and end angles for pattern.
ICHRGE	Charge density flag.
ITYPE	Type of excitation—plane wave and/or voltage sources.
THETA PHI RTH AITH RPH AIPH	Incident plane wave and polarization information.
NWVLT	Number of voltage sources.
NODE RV XV	Wire node number, voltage (Re, Im)
⋮	
FREQ	Frequency of operation.
-1	End of the input.

Table 2.2: DESCRIPTION OF INPUT DATA IN FOR008.DAT

NWNOD NWSEG	Number of nodes and wire segments.
NODE X Y Z	Node number and rectangular coordinates.
⋮	
NSEG NF NT RAD	Segment number, "from" node, "to" node, radius of wire segment.
⋮	

4. IPAT is a flag which should be set to 1 or 2 if a pattern computation is desired or to 0 if it is not. If IPAT is 0 then the data line following it should be omitted. A value of 1 indicates a 3 point quadrature is used; a 2 indicates a 1 point quadrature is used.

5. The line that begins with THETA1 defines the pattern cuts desired. THETA1 and THETA2 specify the starting and ending angles for the pattern computation, and NTHETA specifies the number of evenly spaced angles between THETA1 and THETA2 for the pattern calculation.

6. ICHRGE is a flag which should be set to 1 if charge density output is desired or to 0 if it is not.

7. ITYPE specifies the type of excitation. P indicates a plane wave excitation, V indicates a voltage source excitation.

8. The line beginning with THETA specifies the incident angle and polarization for plane wave scattering. Refer to Fig. 8. This line should always be present. If a scattering problem is not desired, then these parameters may be set to zero.

9. The line beginning with NODE contains information about the location of voltage sources impressed at wire nodes. NODE denotes the wire node (may be a wire-to-surface junction node) number to which a source is to be added. RV and XV specify the values of real and imaginary parts of the voltage source. This line is repeated for each voltage source. The reference direction for voltage sources is the same as the current reference direction (c.f. Section 2.5).

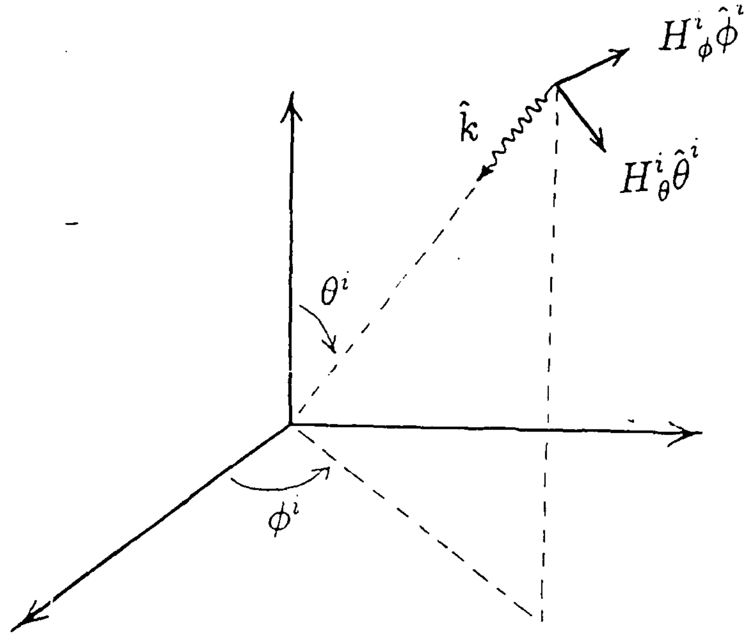

Figure 2.1: Incident field geometrical parameters.

2.4 Modeling Guidelines

1. Triangles may not be imbedded within triangles. Fig. 2.1 shows examples of violations of this rule.

2. For convex bodies, specifying vertices to be on the surface of the original body always results in a triangulated model with reduced surface area and volume as compared to the object being modeled. Thus the solution may appear to correspond to that of an electrically smaller object. This difficulty usually can be substantially corrected by scaling up the object so as to maintain the correct volume or surface area. For this purpose, the surface area and volume of the model are available as output of JUNCTION.

3. At geometrical discontinuities such as edges, corners, wire attachment points, etc., the surface current density usually varies quite rapidly. In such regions, wavelength may have little bearing on the maximum edge length that will yield an accurate solution. Convergence can often be greatly accelerated for such problems by using concentrated mesh schemes in regions where the current varies most rapidly.

4. When modeling closely spaced, almost parallel bodies or wires, the triangulation and segmentation schemes for the parallel surfaces should be made commensurate. Otherwise, modeling-induced discretization of the near field of one surface coupling to the other can produce severe errors in the solution. This problem can also be relieved by choosing edge and segment lengths that are much smaller than the separation distances of the surfaces involved.

5. Segment and triangle edge lengths on wires or in regions on smooth surfaces that are not near surface edges or other geometrical discontinuities, should typically be no longer than 1/5 to 1/10 of a wavelength. This guideline should not, however, be followed blindly. For high-Q resonant structures, such as a resonant length of wire or a narrow tape, for example, it is often found that convergence of the solution as the number of unknowns is increased is very slow and more segments or edges must be used to obtain a solution. Also, very accurate solutions for currents are often required to accurately compute patterns in regions where sidelobe levels are low because the cancellation of the fields in such regions reduces the number of significant figures available. In many practical problems, it is necessary to repeat calculations for several maximum edge or segment lengths in order to check the convergence of the solution.

6. The wire model neglects circumferentially directed currents and any circumferential variation of the axial current; all wire radii must be much smaller than a wavelength at the frequency of excitation for this assumption to remain justified.

7. For wire-to-surface junctions, the wire radii are assumed small compared to the edge lengths of triangles to which they are attached.

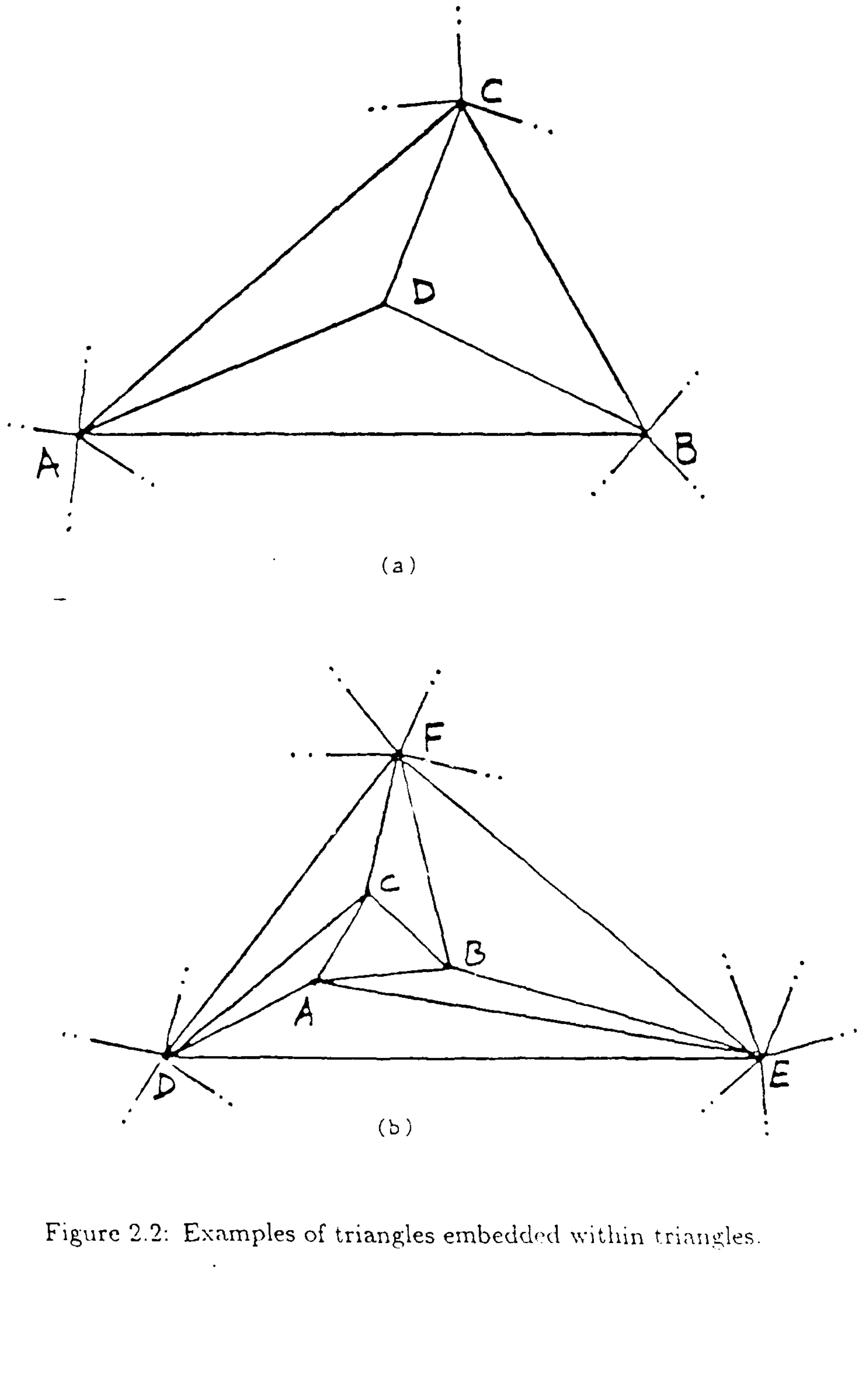

Figure 2.2: Examples of triangles embedded within triangles.

8. If a wire is nearly parallel to a surface at the attachment point, it is assumed that the angle is sufficiently large that the wire-to-surface junction region remains small compared to edge lengths of the attached triangle.

9. For a wire nearly parallel to a surface, the triangular patch density may need to be increased on the surface in the neighborhood of the wire. At wire-to-surface junctions, the junction vertex angles of the junction triangles should be kept small.

2.5 Current Reference Directions

1. The reference current direction on a wire segment is assumed to be from lower numbered to higher numbered segments.

2. The assumed reference direction for the currents across a given edge is determined by the cross product of 1) the edge orientation vector (determined by the "from" and "to" designation in the input data) with 2) the surface normal, taken in that order. The surface normal for a given face is determined from the orientation of the triangle's boundary, as specified by the order in which its edges and/or vertices appear in the output face list. The triangle's normal is merely related to this orientation by the right hand rule. The relationship between face and edge orientations and current reference direction is illustrated in Fig. 2

3. The current reference direction at wire-to-surface junction is into the wire from the surface.

4. For a *closed* surface, the outward normal is automatically chosen by the program. For an *open* surface the following procedure is used to define the normal for one triangular face. Once the normal has been chosen for this face, the program automatically orients the normals for the remaining faces.

   (a) The lowest numbered edge which is connected to edge number 1 and which also forms a triangular face with edge number 1 is found.

   (b) The two edges of the previous step are temporarily treated as vectors directed away from their common vertex. Note that for this purpose, the "from" and "to" vertex designations of the edges are ignored.

   (c) The surface normal is taken to be in the direction of the cross product of these two temporary vectors with edge 1 as the second argument of the cross product. The direction of this normal is then propagated to the adjacent faces and hence over the entire structure.

5. In order to prevent patches from becoming incoherently oriented on intersecting surfaces, it may be necessary to reorient the normals of the intersecting patches manually.

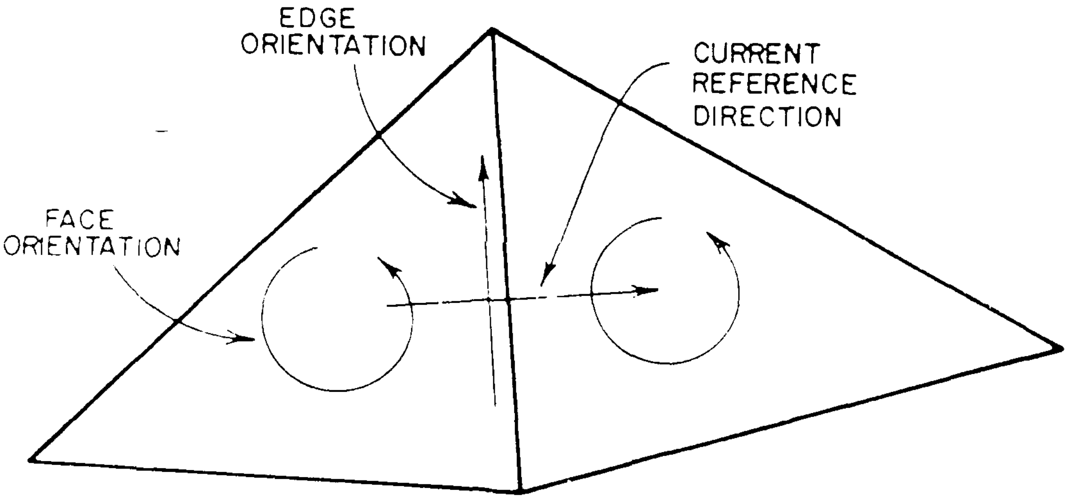

Figure 2.3: The relationship between face and edge orientations and current reference direction.

Chapter 3

Example Problem

The following files were generated by JUNCTION for the simple example problem shown in Fig. 3.1.

1. FOR002.DAT is an input data file associated with the plate.
2. FOR008.DAT is an input data file associated with the wire.
3. NEC.DAT is a NEC formatted geometry data file.
4. IGUANA.NEC is an IGUANA formatted geometry data file.
5. FOR003.DAT is an output data file associated with the plate.
6. FOR009.DAT is an output data file associated with the wire.
7. FOR001.DAT is an output data file for the surface current
8. FOR010.DAT is an output data file for a far field pattern.
9. FOR011.DAT is an output data file for the charge density.

3.1 Geometry

Fig. 3.1 shows the geometry of the example problem. The geometry consists of a 0.15λ length monopole with 0.001λ radius mounted on the center of a $0.2\lambda \times 0.2\lambda$ square plate. The wire was divided into 3 segments and the plate was divided into 8 triangular patches. This is not a sufficient number of wire segments or triangles to accurately model the geometry, but it is sufficient to illustrate the format of the input and output of the program.

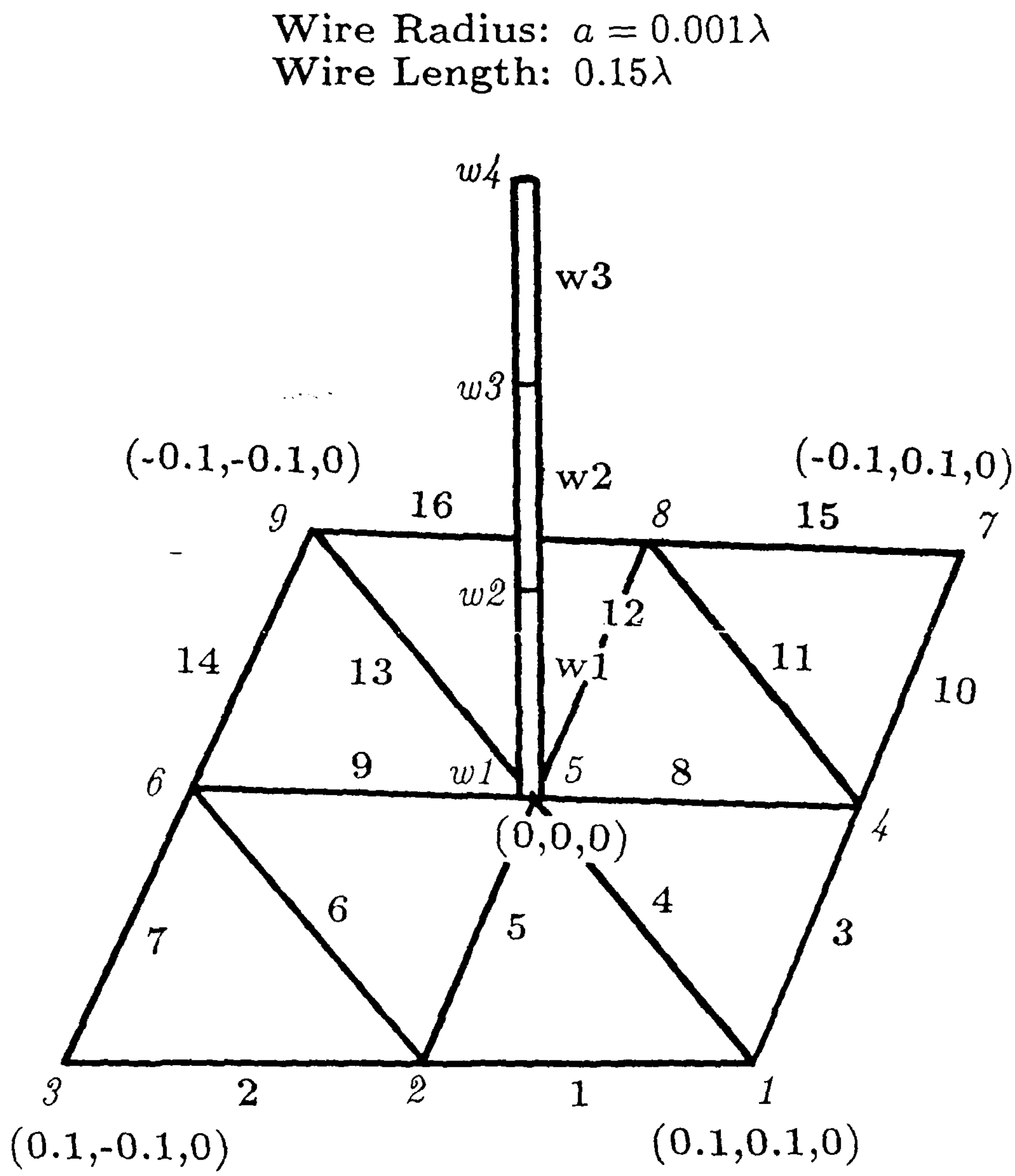

Figure 3.1: Geometry of example problem.

3.2 Input Data

3.2.1 FOR002.DAT

```
C
C FOR002.DAT:INPUT DATA ASSOCIATED WITH BODIES
C
1    1
9   16
1  1.00000001490E-01  1.00000001490E-01  0.00000000000E+00
2  1.00000001490E-01  0.00000000000E+00  0.00000000000E+00
3  1.00000001490E-01 -1.00000001490E-01  0.00000000000E+00
4  0.00000000000E+00  1.00000001490E-01  0.00000000000E+00
5  0.00000000000E+00  0.00000000000E+00  0.00000000000E+00
6  0.00000000000E+00 -1.00000001490E-01  0.00000000000E+00
7 -1.00000001490E-01  1.00000001490E-01  0.00000000000E+00
8 -1.00000001490E-01  0.00000000000E+00  0.00000000000E+00
9 -1.00000001490E-01 -1.00000001490E-01  0.00000000000E+00
    1    1    2
    2    2    3
    3    1    4
    4    1    5
    5    2    5
    6    2    6
    7    3    6
    8    4    5
    9    5    6
   10    4    7
   11    4    8
   12    5    8
   13    5    9
   14    6    9
   15    7    8
   16    8    9
           0
           0           0           0
           2
  0.0000000E+00  0.0000000E+00    1  0.0000000E+00    180.0000
          19
           1
```

```
 V
          1
          1   1.000000       0.0000000E+00
 3.0000000E+08
 -1.000000
```

3.2.2 FOR008.DAT

```
C
C FOR008.DAT : INPUT DATA ASSOCIATED WITH WIRE
C
          4           3
          1  0.0000000E+00  0.0000000E+00  0.0000000E+00
          2  0.0000000E+00  0.0000000E+00  5.0000001E-02
          3  0.0000000E+00  0.0000000E+00  0.1000000
          4  0.0000000E+00  0.0000000E+00  0.1500000
          1           1           2  1.0000000E-03
          2           2           3  1.0000000E-03
          3           3           4  1.0000000E-03
 V
          1
          1   1.000000       0.0000000E+00
```

3.3 Output Data

3.3.1 NEC.DAT

```
C
C NEC.DAT : GEOMETRY DATA IN NEC FORMAT
C
CM INPUT DATA IN NEC FORMAT
CE
GW  0    3   0.0000   0.0000   0.0000   0.0000   0.0000   0.1500   0.0010
SP       2   0.0000   0.0000   0.0000   0.1000   0.0000   0.0000
SC       2   0.1000   0.1000   0.0000
SP       2   0.0000  -0.1000   0.0000   0.1000  -0.1000   0.0000
SC       2   0.1000   0.0000   0.0000
SP       2   0.0000   0.1000   0.0000   0.0000   0.0000   0.0000
SC       2   0.1000   0.1000   0.0000
SP       2   0.0000   0.0000   0.0000   0.0000  -0.1000   0.0000
SC       2   0.1000   0.0000   0.0000
SP       2  -0.1000   0.0000   0.0000   0.0000   0.0000   0.0000
SC       2   0.0000   0.1000   0.0000
SP       2  -0.1000  -0.1000   0.0000   0.0000  -0.1000   0.0000
SC       2   0.0000   0.0000   0.0000
SP       2  -0.1000   0.1000   0.0000  -0.1000   0.0000   0.0000
SC       2   0.0000   0.1000   0.0000
SP       2  -0.1000   0.0000   0.0000  -0.1000  -0.1000   0.0000
SC       2   0.0000   0.0000   0.0000
GE
EN
```

3.3.2 IGU.NEC

```
C
C IGU.NEC : GEOMETRY DATA IN IGUANA FORMAT
C
 CM, INPUT DATA IN IGUANA FORMAT
 CE,
 GW,  1,1,    0.100,    0.100,    0.000,    0.100,    0.000,    0.000,0.1
 GW,  2,1,    0.100,    0.000,    0.000,    0.100,   -0.100,    0.000,0.1
 GW,  3,1,    0.100,    0.100,    0.000,    0.000,    0.100,    0.000,0.1
 GW,  4,1,    0.100,    0.100,    0.000,    0.000,    0.000,    0.000,0.1
 GW,  5,1,    0.100,    0.000,    0.000,    0.000,    0.000,    0.000,0.1
 GW,  6,1,    0.100,    0.000,    0.000,    0.000,   -0.100,    0.000,0.1
 GW,  7,1,    0.100,   -0.100,    0.000,    0.000,   -0.100,    0.000,0.1
 GW,  8,1,    0.000,    0.100,    0.000,    0.000,    0.000,    0.000,0.1
 GW,  9,1,    0.000,    0.000,    0.000,    0.000,   -0.100,    0.000,0.1
 GW, 10,1,    0.000,    0.100,    0.000,   -0.100,    0.100,    0.000,0.1
 GW, 11,1,    0.000,    0.100,    0.000,   -0.100,    0.000,    0.000,0.1
 GW, 12,1,    0.000,    0.000,    0.000,   -0.100,    0.000,    0.000,0.1
 GW, 13,1,    0.000,    0.000,    0.000,   -0.100,   -0.100,    0.000,0.1
 GW, 14,1,    0.000,   -0.100,    0.000,   -0.100,   -0.100,    0.000,0.1
 GW, 15,1,   -0.100,    0.100,    0.000,   -0.100,    0.000,    0.000,0.1
 GW, 16,1,   -0.100,    0.000,    0.000,   -0.100,   -0.100,    0.000,0.1
 GW,999,  3,    0.00,    0.00,    0.00,    0.00,    0.00,    0.15,  0.0010
 GE,
 EN,
```

3.3.3 FOR003.DAT

```
C
C FOR003.DAT: OUTPUT DATA ASSOCIATED WITH BODIES
C
 NUMBER OF JUNCTION=  1
 ON WIRE NODE 1

 NUMBER OF IMAGE PLANES=  0
 IMAGE PLANE NOTATION:
        0=NO GROUND PLANE
        1=A P.M.C. GROUND PLANE
       -1=A P.E.C. GROUND PLANE
   0 IN THE X=0 PLANE
   0 IN THE Y=0 PLANE
   0 IN THE Z=0 PLANE

 NUMBER OF VOLTAGE SOURCE =  1
 V=(1.0,0.0) VOLTS ON WIRE NODE 1

                    VERTEX  COORDINATE  LIST
                  ALL DIMENSIONS ARE IN METERS


 VERTEX NUMBER   X-COORDINATE  Y-COORDINATE  Z-COORDINATE
      1           0.10000E+00   0.10000E+00   0.00000E+00
      2           0.10000E+00   0.00000E+00   0.00000E+00
      3           0.10000E+00  -0.10000E+00   0.00000E+00
      4           0.00000E+00   0.10000E+00   0.00000E+00
      5           0.00000E+00   0.00000E+00   0.00000E+00
      6           0.00000E+00  -0.10000E+00   0.00000E+00
      7          -0.10000E+00   0.10000E+00   0.00000E+00
      8          -0.10000E+00   0.00000E+00   0.00000E+00
      9          -0.10000E+00  -0.10000E+00   0.00000E+00


 IPAT=    2
 IF IPAT.GT.0 FAR FIELD PATTERNS ARE COMPUTED
 PATTERN PARAMETERS:
 PHI1,     PHI2,   NPHI, THETA1,  THETA2,  NTHETA
```

```
0.0000    0.0000    1    0.0000  180.0000    19
```

FOR BODY NUMBER: 1

```
FACE  1 HAS EDGES   1   4   5 WITH VERTICES  5  2  1
FACE  2 HAS EDGES   2   6   7 WITH VERTICES  6  3  2
FACE  3 HAS EDGES   4   3   8 WITH VERTICES  4  5  1
FACE  4 HAS EDGES   6   5   9 WITH VERTICES  5  6  2
FACE  5 HAS EDGES   8  11  12 WITH VERTICES  8  5  4
FACE  6 HAS EDGES   9  13  14 WITH VERTICES  9  6  5
FACE  7 HAS EDGES  11  10  15 WITH VERTICES  7  8  4
FACE  8 HAS EDGES  13  12  16 WITH VERTICES  8  9  5
```

EDGE-VERTEX CONNECTION LIST

```
EDGE   1 GOES FROM VERTEX  1 TO VERTEX  2 MULT= 0
EDGE   2 GOES FROM VERTEX  2 TO VERTEX  3 MULT= 0
EDGE   3 GOES FROM VERTEX  1 TO VERTEX  4 MULT= 0
EDGE   4 GOES FROM VERTEX  1 TO VERTEX  5 MULT= 1
EDGE   5 GOES FROM VERTEX  2 TO VERTEX  5 MULT= 1
EDGE   6 GOES FROM VERTEX  2 TO VERTEX  6 MULT= 1
EDGE   7 GOES FROM VERTEX  3 TO VERTEX  6 MULT= 0
EDGE   8 GOES FROM VERTEX  4 TO VERTEX  5 MULT= 1
EDGE   9 GOES FROM VERTEX  5 TO VERTEX  6 MULT= 1
EDGE  10 GOES FROM VERTEX  4 TO VERTEX  7 MULT= 0
EDGE  11 GOES FROM VERTEX  4 TO VERTEX  8 MULT= 1
EDGE  12 GOES FROM VERTEX  5 TO VERTEX  8 MULT= 1
EDGE  13 GOES FROM VERTEX  5 TO VERTEX  9 MULT= 1
EDGE  14 GOES FROM VERTEX  6 TO VERTEX  9 MULT= 0
EDGE  15 GOES FROM VERTEX  7 TO VERTEX  8 MULT= 0
EDGE  16 GOES FROM VERTEX  8 TO VERTEX  9 MULT= 0
```

BODY PARAMETER LIST

```
NUMBER OF VERTICES=   9
NUMBER OF EDGES=  16
NUMBER OF FACES=   8
```

```
          NUMBER OF EDGES INCLUDING MULTIPLICITY=   8


                         MODELING PARAMETER LIST (METERS)

SURFACE AREA OF THE SCATTERER= 0.40000E-01 SQ.METERS
AVERAGE EDGE LENGTH= 0.12071E+00 METERS
MAXIMUM EDGE LENGTH(EDGE NO.  4 )= 0.14142E+00 METERS
MINIMUM EDGE LENGTH(EDGE NO.  1 )= 0.10000E+00 METERS
AVERAGE FACE AREA = 0.50000E-02 SQ.METERS
MAXIMUM FACE AREA (FACE NO.   1 )= 0.50000E-02 SQ.METERS
MINIMUM FACE AREA (FACE NO.   1 )= 0.50000E-02 SQ.METERS
MINIMUM FACE HEIGHT TO BASE RATIO (FACE NO.   1 )=0.50000E+00

 EDGE   1 IS ATTACHED TO FACES
          1
 EDGE   2 IS ATTACHED TO FACES
          2
 EDGE   3 IS ATTACHED TO FACES
          3
 EDGE   4 IS ATTACHED TO FACES
          1            3
 EDGE   5 IS ATTACHED TO FACES
          1            4
 EDGE   6 IS ATTACHED TO FACES
          2            4
 EDGE   7 IS ATTACHED TO FACES
          2
 EDGE   8 IS ATTACHED TO FACES
          3            5
 EDGE   9 IS ATTACHED TO FACES
          4            6
 EDGE  10 IS ATTACHED TO FACES
          7
 EDGE  11 IS ATTACHED TO FACES
          5            7
 EDGE  12 IS ATTACHED TO FACES
          5            8
 EDGE  13 IS ATTACHED TO FACES
          6            8
```

```
EDGE  14 IS ATTACHED TO FACES
        6
EDGE  15 IS ATTACHED TO FACES
        7
EDGE  16 IS ATTACHED TO FACES
        8

FREQ= 3.00000E+08
```

SURFACE CURRENTS

EDGE NUMBER	CURRENT DENSITY (AMPS/METER)			
	REAL	IMAGINARY	MAGNITUDE	PHASE(DEG)
1	0.00000E+00	0.00000E+00	0.00000E+00	
2	0.00000E+00	0.00000E+00	0.00000E+00	
3	0.00000E+00	0.00000E+00	0.00000E+00	
4	-0.13488E-09	-0.64974E-08	0.64988E-08	90.000
5	0.60283E-05	0.51320E-03	0.51324E-03	89.327
6	0.13376E-03	0.42825E-02	0.42846E-02	88.211
7	0.00000E+00	0.00000E+00	0.00000E+00	
8	-0.60286E-05	-0.51321E-03	0.51325E-03	-90.673
9	0.60279E-05	0.51321E-03	0.51324E-03	89.327
10	0.00000E+00	0.00000E+00	0.00000E+00	
11	-0.13376E-03	-0.42825E-02	0.42846E-02	-91.789
12	-0.60277E-05	-0.51320E-03	0.51323E-03	-90.673
13	0.24486E-09	0.83496E-08	0.83532E-08	90.000
14	0.00000E+00	0.00000E+00	0.00000E+00	
15	0.00000E+00	0.00000E+00	0.00000E+00	
16	0.00000E+00	0.00000E+00	0.00000E+00	

3.3.4 FOR009.DAT

```
C
C FOR009.DAT : OUTPUT DATA ASSOCIATED WITH WIRE
C
        NODES       SEGMENTS
          4            3

        NODE #      X               Y               Z
          1  0.0000000E+00  0.0000000E+00  0.0000000E+00
          2  0.0000000E+00  0.0000000E+00  5.0000001E-02
          3  0.0000000E+00  0.0000000E+00  0.1000000
          4  0.0000000E+00  0.0000000E+00  0.1500000

        SEG. #       FROM          TO      RADIUS
          1            1            2  1.0000000E-03
          2            2            3  1.0000000E-03
          3            3            4  1.0000000E-03

        SEG. #         CENTER POINT COORDINATES
          1  0.0000000E+00  0.0000000E+00  2.5000000E-02
          2  0.0000000E+00  0.0000000E+00  7.5000003E-02
          3  0.0000000E+00  0.0000000E+00  0.1250000

        TOTAL UNKNOWN NUMBER = 3

        NODE #     MULTIPLICITY
          1            1
          2            1
          3            1
          4            0

                             SURFACE CURRENTS

 EDGE NUMBER              CURRENT DENSITY (AMPS/METER)
             REAL          IMAGINARY        MAGNITUDE        PHASE(DEG)
     1    0.12649E-03    0.50176E-02     0.50192E-02         88.556
     2    0.11298E-03    0.35006E-02     0.35024E-02         88.152
     3    0.72494E-04    0.18988E-02     0.19002E-02         87.814
     4    0.00000E+00    0.00000E+00
```

3.3.5 FOR004.DAT

```
C
C FOR004.DAT : SURFACE CURRENT LISTING
C
 FREQ= 3.00000E+08
```

SURFACE CURRENTS

EDGE NUMBER	CURRENT DENSITY (AMPS/METER) REAL	IMAGINARY	MAGNITUDE	PHASE(DEG)
1	0.00000E+00	0.00000E+00	0.00000E+00	
2	0.00000E+00	0.00000E+00	0.00000E+00	
3	0.00000E+00	0.00000E+00	0.00000E+00	
4	-0.13488E-09	-0.64974E-08	0.64988E-08	90.000
5	0.60283E-05	0.51320E-03	0.51324E-03	89.327
6	0.13376E-03	0.42825E-02	0.42846E-02	88.211
7	0.00000E+00	0.00000E+00	0.00000E+00	
8	-0.60286E-05	-0.51321E-03	0.51325E-03	-90.673
9	0.60279E-05	0.51321E-03	0.51324E-03	89.327
10	0.00000E+00	0.00000E+00	0.00000E+00	
11	-0.13376E-03	-0.42825E-02	0.42846E-02	-91.789
12	-0.60277E-05	-0.51320E-03	0.51323E-03	-90.673
13	0.24486E-09	0.83496E-08	0.83532E-08	90.000
14	0.00000E+00	0.00000E+00	0.00000E+00	
15	0.00000E+00	0.00000E+00	0.00000E+00	
16	0.00000E+00	0.00000E+00	0.00000E+00	
1	0.12649E-03	0.50176E-02	0.50192E-02	88.556
2	0.11298E-03	0.35006E-02	0.35024E-02	88.152
3	0.72494E-04	0.18988E-02	0.19002E-02	87.814
4	0.00000E+00	0.00000E+00		

3.3.6 FOR010.DAT

```
C
C FOR010.DAT : FAR FIELD PATTERN LISTING
C
                          FAR FIELD PATTERN

 ITHETA  THETA  IPHI  PHI   ETH(ITHETA,IPHI)     EPH(ITHETA,IPHI)

    1      0.00    1    0.00 -4.66E-10 -9.81E-10  8.03E-09 -1.34E-09
    2     10.00    1    0.00 -1.20E-02 -5.22E-03  4.46E-06  1.15E-04
    3     20.00    1    0.00 -2.38E-02 -9.80E-03  8.77E-06  2.26E-04
    4     30.00    1    0.00 -3.52E-02 -1.32E-02  1.28E-05  3.30E-04
    5     40.00    1    0.00 -4.58E-02 -1.49E-02  1.64E-05  4.23E-04
    6     50.00    1    0.00 -5.54E-02 -1.47E-02  1.95E-05  5.03E-04
    7     60.00    1    0.00 -6.35E-02 -1.26E-02  2.19E-05  5.68E-04
    8     70.00    1    0.00 -6.96E-02 -8.67E-03  2.38E-05  6.15E-04
    9     80.00    1    0.00 -7.34E-02 -3.49E-03  2.49E-05  6.43E-04
   10     90.00    1    0.00 -7.45E-02  2.34E-03  2.52E-05  6.53E-04
   11    100.00    1    0.00 -7.30E-02  8.09E-03  2.49E-05  6.43E-04
   12    110.00    1    0.00 -6.89E-02  1.30E-02  2.38E-05  6.15E-04
   13    120.00    1    0.00 -6.26E-02  1.65E-02  2.19E-05  5.68E-04
   14    130.00    1    0.00 -5.44E-02  1.81E-02  1.95E-05  5.03E-04
   15    140.00    1    0.00 -4.48E-02  1.77E-02  1.64E-05  4.23E-04
   16    150.00    1    0.00 -3.43E-02  1.53E-02  1.28E-05  3.30E-04
   17    160.00    1    0.00 -2.31E-02  1.13E-02  8.77E-06  2.26E-04
   18    170.00    1    0.00 -1.16E-02  5.95E-03  4.46E-06  1.15E-04
   19    180.00    1    0.00  4.66E-10  9.81E-10  8.03E-09 -1.34E-09
```

3.3.7 FOR011.DAT

```
C
C FOR011.DAT : CHARGE DENSITY LISTING
C
                       SURFACE CHARGE

 FACE NUMBER         CHARGE DENSITY (COULOMBS/SQ.METER)

            REAL             IMAGINARY        MAGNITUDE          PHASE
 1      -0.6110300E-10    0.1613704E-11    0.6112431E-10    0.1784872E+03
 2      -0.6426055E-10    0.2007158E-11    0.6429188E-10    0.1782110E+03
 3      -0.6110310E-10    0.1613705E-11    0.6112440E-10    0.1784872E+03
 4      -0.7972668E-10    0.1476099E-11    0.7974035E-10    0.1789393E+03
 5      -0.7972668E-10    0.1476101E-11    0.7974035E-10    0.1789393E+03
 6      -0.6110314E-10    0.1613713E-11    0.6112445E-10    0.1784872E+03
 7      -0.6426052E-10    0.2007157E-11    0.6429186E-10    0.1782110E+03
 8      -0.6110301E-10    0.1613709E-11    0.6112431E-10    0.1784872E+03

   TOTAL CHARGE ON THE BODY= ( -0.2661934E-11  0.6710674E-13 ) COULOMBS

                       CHARGE DENSITY ON WIRE

 SEGMENT NUMBER          CHARGE DENSITY  (COULOMBS/METER)

            REAL             IMAGINARY        MAGNITUDE          PHASE
 1       0.1609630E-10   -0.1434157E-12    0.1609694E-10   -0.5104834E+00
 2       0.1699554E-10   -0.4295376E-12    0.1700096E-10   -0.1447760E+01
 3       0.2014683E-10   -0.7691813E-12    0.2016151E-10   -0.2186421E+01

   TOTAL CHARGE ON THE WIRE= (  0.2661934E-11 -0.6710673E-13 ) COULOMBS
```

Bibliography

[1] D. R. Wilton and S. U. Hwu, "Electromagnetic Scattering and Radiation by Arbitrary Configurations of Conducting Bodies and Wires," Technical Report No. 87-17, Applied Electromagnetics Lab., Dept. of Electrical Engr., Univ. of Houston, 1987.

[2] J.Strauch,"User's Guide for the Interactive Graphics Utility for Automated NEC Analysis (IGUANA) for version 4.1", Unisys Corporation, San Diego, CA, July 1987.

[3] G. J. Burke and A. J. Poggio, "Numerical Electromagnetic Code (NEC) - Method of Moments," Lawrence Livermore Laboratory, Jan. 1981.

[4] W. A. Johnson, D. R. Wilton and R. M. Sharpe, "PATCH Code Users Manual," Sandia National Laboratories, Albuquerque, N.M. 87185, 1987.

[5] J. Dongarra, J. R. Bunch, C. B. Moler, and G. W. Stewart. *LINPACK Users Guide*. SIAM Publications, 1978.

Appendix A

Program Listings

Following is a FORTRAN listing of the computer program JUNCTION and its supporting subprograms. Only the called LINPACK [5] subroutines CGEFA and CGESL, which solve linear systems of simultaneous equations are not included in the listing. If these routines are not readily available, any equivalent equation-solving subroutines can be substituted.

A.1 JUNCTION

```
C                    PROGRAM JUNCTION V1.1
C-------------------------------------------------------------------
C
C ELECTROMAGNETIC SCATTERING AND RADIATION BY WIRES ATTACHED TO
C           CONDUCTING SURFACES OF ARBITRARY SHAPE
C
C                      SHIAN-UEI HWU
C                 APPLIED ELECTROMAGNETICS LAB
C                    UNIVERSITY OF HOUSTON
C
C                     HOUSTON, TX77004
C
C
C THIS PROGRAM WAS DEVELOPED AS AN EXTENSION OF THE ELECTRIC FIELD
C INTEGRAL EQUATION SURFACE PATCH CODE AND THIN WIRE CODE
C
C ORIGINAL PATCH VERSION BY S. M. RAO
C ORIGINAL WIRE VERSION BY S. SINGH
C
C REORGANIZATION AND EXTENSIONS BY W. A. JOHNSON OF
C SANDIA NATIONAL LAB 1984
C
C INPUT DATA IN FOR002.DAT(BODIES) AND FOR008.DAT(WIRES)
C OUTPUT DATA IN FOR003.DAT,FOR004.DAT(BODIES), FOR009.DAT(WIRES)
C MODELING CAPABILITIES INCLUDE SYMMETRY PLANES AND/OR GROUND PLANES
C-------------------------------------------------------------------
C I. MAIN :
C      1. DATGEN : TO CREATE INPUT DATA OF BODY AND WIRE
C         1.1. WIRDAT : TO CREATE A STRAIGHT WIRE
C         1.2. NECDAT : TO READ INPUT DATA IN NEC FORMATE
C      2. BODIN : TO READ INPUT DATA ASSOCIATE WITH BODIES
C      3. WIRIN : TO READ INPUT DATA ASSOCIATE WITH WIRES
C         3.1. FNDJUN : TO FIND JUNCTION NODES IF THERE ARE ANY
C         3.2. WIRMUL : TO FIND MULTIPLICITY OF WIRE SEGMENTS
C      4. ADWMUL : TO ADJUST MULTIPLICITY OF EACH WIRE NODE IF
C                 THERE ARE ANY GROUNG PLANE ATTACHED
C      5. FACMUL : TO FIND FACES DATALIST OF BODIES
C      6. ORTFAC : TO ORIENT THE FACE OF BODIES
C      7. CLSBOD : TO FIND NORMAL VECTOR OF CLOSED BODY
C         7.1. FACEDG : TO FIND EDGES ASSOCIATED WITH FACE
C         7.2. FACVTX: TO FIND VERTICES ASSOCIATED WITH FACE
C         7.3. VTXCRD: TO FIND COORDINATES OF THE VERTICES
C      8. FACOUT : TO PRINT THE EDGES AND THE VERTICES OF EACH FACE
```

```
C         8.2. FACVTX: TO FIND VERTICES ASSOCIATED WITH FACE
C      9. ADBMUL : TO ADJUST MULTIPLICITY OF EACH EDGE IF
C               THERE ARE ANY GROUNG PLANE ATTACHED
C     10. BODPAR : TO CALCULATE PARAMETERS ASSOCIATED WITH BODIES
C        10.2. FACVTX: TO FIND VERTICES ASSOCIATED WITH FACE
C        10.3. VTXCRD: TO FIND COORDINATES OF THE VERTICES
C     11. EDGFAC : TO FIND FACES ATTACHED TO EACH EDGE
C     12. SOLTN : TO SOLVE THE MATRIX EQUATION
C         12.1. JUNFAC : TO FIND FACES ATTACHED TO EACH JUNCTION
C         12.2. JANGLE : TO FIND VERTEX ANGLE OF EACH JUNCTION FACE
C         12.3. BCUMUL : TO ACCUMULATE THE MULTIPLICITIES UP TO
C                        EACH EDGE
C         12.4. MTXWIR : TO FILL IMPEDANCE MATRIX
C                       FOR SOURCE ON THE WIRES
C         12.5. ZBB :TO FILL IMPEDANCE MATRIX
C                       FOR SOURCE AND OBSERVATION ON THE BODIES
C         12.6. ZWB :TO FILL IMPEDANCE MATRIX
C                       FOR SOURCE ON THE BODIES AND OBSERVATION
C                       ON THE WIRES
C         12.7. CGEFA : TO INVERSE THE IMPEDANCE MATRIX
C         12.8. CGESL : TO SOLVE THE UNKNOWN MATRIX
C
C-----------------------------------------------------------------------
*  MXUNKN = MAXIMUM NUMBER OF UNKNOWNS EXPECTED.                       *
C
C BODIES:
C MXEDGS=MAXIMUN NUMBER OF EDGES EXPECTED
C MXBDND=MAXIMUN NUMBER OF NODES EXPECTED
C MXFACE=MAXIMUN NUMBER OF FACES EXPECTED
C MXDJBD=MAXIMUN NUMBER OF DISJOINT BODIES EXPECTED
C MXMULT=MAXIMUM MULTIPLICITY OF ANY EDGE OVER ALL EDGES
C MXEXCI=MAXIMUM NUMBER OF EXCITATIONS.
C MXFREQ=MAXIMUM NUMBER OF FREQUENCY CASES TO BE RUN.
C MNJFACE:MAXIMUN NUMBER OF FACE ATTACHING TO JUNCTION POINT
C
*  WIRES:
*  MXWNOD = MAXIMUM NUMBER OF WIRE NODES.                              *
*  MXWMLT = MAXIMUM MULTIPLICITY THAT ANY WIRE NODE MAY HAVE.          *
*  MXWSEG = MAXIMUM NUMBER OF WIRE SEGMENTS.                           *
*  MXWVLT = MAXIMUM NUMBER OF DELTA GAP VOLTAGE SOURCES ON THE WIRES.  *
C=======================================================================
      PROGRAM JUNCTION
      IMPLICIT COMPLEX(C)
C
C 732 IS THE MAXIMUN DIMENSION CAN BE RUN ON GEORGE (VAX8530 IN UH)
```

```
C      PARAMETER(MXUNKN= 732,MXBDND= 500,MXEDGS= 732,MXFACE= 600,
C
C FOR BODIES
C
      PARAMETER(MXUNKN= 600,MXBDND= 250,MXEDGS= 600,MXFACE= 500,
     $      MXDJBD=1,MXMULT= 2,MXEXCI=1,MXFREQ=1,MNJFACE= 34)
C
C FOR WIRES
C
      PARAMETER(MXWNOD= 41,MXWMLT=1,MXWSEG= 41,MXWVLT=2)
      COMPLEX CZ(MXUNKN,MXUNKN),CV(MXUNKN),CWORK(MXUNKN),CWVLT(MXWVLT)
      INTEGER NCONN(3,MXEDGS),IWORK(MXEDGS),NBOUND(3,MXFACE),
     $            ISTART(MXDJBD+1),NBE(MXDJBD),IPVT(MXUNKN),
     $            IEDGF(MXMULT+1,MXEDGS),IGNDP(3),NBJUN(MXWNOD),
     $            NWJUN(MXWNOD),MULTW(MXWNOD),NSEGC(2,MXWSEG),
     $            INSEG(MXWMLT+1,MXWNOD),NODVLT(MXWVLT)
      REAL DATNOD(3,MXBDND),EXCITE(7,MXEXCI),
     $            WNODE(3,MXWNOD),WSEGH(3,MXWSEG),RAD(MXWSEG)
C
C FOR WIRE
C
      REAL ANG(MXWNOD,MNJFACE)
      INTEGER NJFACE(MXWNOD,MNJFACE),MIFACE(MXWNOD),WIRSUM(MXWNOD)
      CHARACTER*1 ID,IG,IC,IS
      CHARACTER*15 NECNAM,IGUNAM
C
      COMMON/TEST/RATIO1,RATIO2,RATIO3
      COMMON/MCHVAL/VALMAX,VALMIN
      COMMON/IGUANA/IG
      COMMON/CPU/TGG,IC
      MULT1=MXMULT+1
      VALMAX= 1E35
      VALMIN=-1E35
C
C SET TESTING BOUNDARY TO USE 1,3, OR 7 SAMPLING POINTS
C IN NUMERICAL INTEGRATION
C
      RATIO1=1.
      RATIO2=9.
      RATIO3=100.
C INPUT DATA IN FOR002.DAT(BODIES) AND FOR008.DAT(WIRES)
C OUTPUT DATA IN FOR003.DAT,FOR004.DAT(BODIES), FOR009.DAT(WIRES)
        WRITE(6,*)'-------------------------------------'
        WRITE(6,*)'      MOMENT METHOD SOLUTION '
        WRITE(6,*)'WIRES ATTACHED TO CONDUCTING SURFACES '
```

```
      WRITE(6,*)'--------------------------------------'
      WRITE(6,*)' '
C
C CALL DATGEN TO GENERATE INPUT DATA FOR BODY AND WIRE
C
      WRITE(6,*)'DO YOU WANT TO GENERATE INPUT DATA? (YES OR NO)'
55    CALL EOFCLR(5)
      READ(5,5,END=55)ID
5     FORMAT(A)
      IF(ID.EQ.'Y')THEN
      CALL DATGEN
      WRITE(6,*)'*** INPUT DATA CREATED ***'
      WRITE(6,*)' '
      ELSE
      WRITE(6,*)'IF INPUT DATA EXIST SHOULD BE AS FOR002.DAT(BODIES)
     $AND FOR008.DAT(WIRES)'
      WRITE(6,*)' '
      ENDIF
      WRITE(6,*)'DO YOU WANT TO TRANSFER INPUT DATA TO NEC AND IGUANA
     $ FORMAT? (YES OR NO)'
56    CALL EOFCLR(5)
      READ(5,5,END=56)IG
      IF(IG.EQ.'Y')THEN
      WRITE(6,*)'GIVE A FILENAME TO NEC FORMAT DATA FILE'
57    CALL EOFCLR(5)
      READ(5,5,END=57)NECNAM
C
      WRITE(6,*)'GIVE A FILENAME TO IGUANA FORMAT DATA FILE (name.NEC)'
58    CALL EOFCLR(5)
      READ(5,5,END=58)IGUNAM
      ENDIF
C
      WRITE(6,*)'DO YOU WANT TO STOP TO CHECK GEOMETRY DATA ?
     $ (YES OR NO)'
59    CALL EOFCLR(5)
      READ(5,5,END=59)IS
C
      IF(IS.NE.'Y')THEN
      WRITE(6,*)'DO YOU WANT TO SHOW CPUTIME? (YES OR NO)'
61    CALL EOFCLR(5)
      READ(5,5,END=61)IC
      ENDIF
C
C CALL RUNTIME LIBRARY
C
```

```
      IERR=LIB$ERASE_PAGE(1,1)
C
      IERR=LIB$INIT_TIMER( )
C
C OPEN I/O FILES
C
      OPEN(2,FILE='FOR002.DAT',TYPE='OLD')
      REWIND(2)
      READ(2,*)NJCT
      REWIND(2)
      IF(NJCT.GE.0)THEN
      OPEN(8,FILE='FOR008.DAT',TYPE='OLD')
      REWIND(8)
      ENDIF
      IF(IG.EQ.'Y')THEN
      OPEN(12,FILE=NECNAM,TYPE='NEW')
      REWIND(12)
      OPEN(18,FILE=IGUNAM,TYPE='NEW')
      REWIND(18)
      ENDIF
C
C READ INPUT DATA ASSOCIATE WITH BODIES
C
      CALL BODIN(MXBDND,MXEDGS,DATNOD,NCONN,NNODES,
     $NEDGES,MXEXCI,EXCITE,NEXCIT,NJCT,MNJUN,MXWVLT,NWVLT,
     $NODVLT,CWVLT,IPAT,ITOT)
C
C NBJUN(I):BODY NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C NWJUN(I):WIRE NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C
      IF(NJCT.GE.0) THEN
C
C READ INPUT DATA ASSOCIATE WITH WIRES
C
      CALL WIRIN(MXWNOD,MXWMLT,MXWSEG,NWNOD,NWSEG,NWUNKS,WNODE,MULTW,
     $     NSEGC,WSEGH,RAD,INSEG,DATNOD,NNODES,NJCT,MNJUN,NWJUN,NBJUN)
C
C  TO RECALCULATE MULTIPLICITY OF EACH WIRE NODE IF
C               THERE ARE ANY GROUNG PLANE ATTACHED
C
      CALL ADWMUL(NWNOD,WNODE,MULTW,NWUNKS)
      ELSE
C
C TO AVOID ZERO DIMENSIONAL ARRAY
C
```

```
      NWNOD=1
      NWSEG=1
      NWUNKS=0
      ENDIF
C
C TO FIND FACES DATALIST OF BODIES
C
      CALL FACMUL(NCONN,NEDGES,IWORK,NBOUND,MXFACE,NFACES,NUNKNB)
C
C TO NUMBER ALL EDGES OF BODIES
C
      CALL ORTFAC(NCONN,NBOUND,NFACES,NEDGES,MXDJBD,IWORK,ISTART,NBODYS,
     $             NBE)
      DO 10 I=1,NBODYS
C
C       TO FIND NORMAL VECTOR OF CLOSED BODY
C
        IF(NBE(I).EQ.0)CALL CLSBOD(DATNOD,NCONN,NBOUND,NNODES,NEDGES,
     $                 NFACES,I,ISTART)
C
C       TO PRINT THE EDGES AND THE VERTICES OF EACH FACE
C
        CALL FACOUT(NCONN,NBOUND,ISTART,I,NEDGES,NFACES,NBODYS,
     $ DATNOD,NNODES)
C
   10   CONTINUE
C
         IF(IS.EQ.'Y')THEN
         WRITE(6,*)'  '
         WRITE(6,*)'*** INPUT DATA FILE IN NEC FORMAT COMPLETED ***'
         WRITE(6,*)'  '
         WRITE(6,*)'*** INPUT DATA FILE IN IGUANA FORMAT COMPLETED ***'
         WRITE(6,*)'  '
         WRITE(6,*)'*** USE MODEL MAKER IN IGUANA TO PLOT GEOMETRY **'
         WRITE(6,*)'  '
         WRITE(6,*)'*** IF DATA TRANSFER TO OTHER COMPUTER SYSTEM CHECK
     $ DATA AGAIN **'
         WRITE(6,*)'  '
         STOP
         ENDIF
C
C      EDGEP : TO RECALCULATE MULTIPLICITY OF EACH EDGE IF
C                  THERE ARE ANY GROUNG PLANE ATTACHED
C      BODPAR : TO CALCULATE PARAMETERS ASSOCIATED WITH BODIES
C      EDGFAC : TO FIND FACES ATTACHED TO EACH EDGE
```

```
C
      CALL ADBMUL(NNODES,NEDGES,DATNOD,NCONN,NUNKNB)
      CALL BODPAR(DATNOD,NCONN,NBOUND,NNODES,NEDGES,NFACES,NUNKNB)
      CALL EDGFAC(NCONN,NEDGES,NBOUND,NFACES,IEDGF,MULT1)
C
C NUNKNT: NUMBER OF TOTAL UNKNOWNS
C NUNKNB: NUMBER OF BODIES UNKNOWNS
C NWUNKS: NUMBER OF WIRES UNKNOWNS
C
      NUNKNT=NUNKNB+NWUNKS
C
C CHECK IF DECLARED DIMENSION IS ENOUGH
C
      IF(NUNKNT.GT.MXUNKN) THEN
      WRITE(6,*)'DECLARED DIMENSION FOR TOTAL UNKNOWNS
     $ IS INSUFFICIENT'
      STOP
      ENDIF
C
      WRITE(6,*)'*** GEOMETRY PART COMPLETED ***'
C
      IF(IC.EQ.'Y')THEN
C
      IERR=LIB$STAT_TIMER( 2, ITG1, )
      TGG=FLOAT(ITG1)/6000.
C
      WRITE(6,*)'CPUTIME FOR GEOMETRY = ',TGG,' MINUTES'
      ENDIF
C
      WRITE(6,*)' '
      WRITE(6,*)' EXECUTION ........'
C
C TO FILL AND SOLVE THE MATRIX EQUATION
C
      CALL SOLTN(CZ,CV,NUNKNT,IPVT,CWORK,DATNOD,NCONN,NBOUND,NEDGES,
     $    NFACES,NNODES,IEDGF,MULT1,EXCITE,NEXCIT,
     $    MXFREQ,IWORK,NUNKNB,NWNOD,NWSEG,NWUNKS,WNODE,MULTW,NSEGC,
     &    WSEGH,RAD,INSEG,NJCT,MNJUN,NWJUN.NBJUN,
     &    WIRSUM,ANG,MNJFACE,NJFACE,MIFACE,MXWMLT,NWVLT,NODVLT,CWVLT,
     &    IPAT,ITOT)
      END
```

A.2 DATGEN

```
C=============================================================
      SUBROUTINE DATGEN
C-------------------------------------------------------------
* THIS SUBROUTINE CREATES INPUT DATA FOR BODY AND WIRE
* FOR JUNCTION PROGRAM
* MXFACE=MAXIMUN NUMBER OF FACES EXPECTED.
* MXBNOD=MAXIMUM NUMBER OF BODY NODES.
* MXBEDG=MAXIMUM NUMBER OF BODY EDGES.
* CLOSE=THE MAXIMUM SPACE BETWEEN TWO POINTS AND STILL ATTACH.
C-------------------------------------------------------------
      PARAMETER(MXBNOD=1000,MXBEDG=1000,MXFACE=1000)
      PARAMETER(CLOSE=1.E-4)
C
      CHARACTER*1 ID,IN
 1    FORMAT(A1)
      INTEGER IBEDGE(2,MXBEDG),IFACES(3,MXFACE),ITRAK(MXBEDG/2)
      REAL    BNODES(3,MXBNOD)
C
      COMMON /BODY/  NBNODS,NBEDGS,NFACES
      COMMON /SPACE/ SPACE
C
      SPACE=CLOSE
      ID='N'
      IF(ID.EQ.'Y')THEN
        CALL READIN(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'N')THEN
      PRINT*,'***** DEFINE THE BODY AND WIRE *****'
      PRINT*,'HOW MANY BODY/WIRE JUNCTIONS ?'
      PRINT*,'IF NO JUNCTION TYPE 0'
      PRINT*,'IF NO WIRE TYPE -1'
 100  CALL EOFCLR(5)
        READ(5,*,END=100)NJUN
        NBNODS=0
        NBEDGS=0
      ELSEIF(ID.EQ.'Q')THEN
        GOTO 999
      ELSE
        GOTO 100
      ENDIF
 200  CALL EOFCLR(5)
      PRINT*,'DO YOU WISH TO'
      PRINT*,'  Z  READ GEOMETRY DATA IN NEC FORMAT'
      PRINT*,'  A  CREATE A QUADRANGLE'
```

```
      PRINT*,'  B  CREATE A CYLINDER'
      PRINT*,'  C  CREATE A CONE'
      PRINT*,'  D  CREATE A DISK'
      PRINT*,'  E  CREATE A SPHERE'
      PRINT*,'  G  CREATE A STRAIGHT WIRE'
      PRINT*,'  H  QUERY NODES, EDGES, AND/OR FACES'
      PRINT*,'  I  ADD, DELETE, OR MOVE A NODE OR EDGE'
      PRINT*,'  J  ENTER TEST DATA'
      PRINT*,'  K  START OVER'
      PRINT*,'  Q  QUIT - SAVE NOTHING'
      PRINT*,'INPUT "Z" "A-K" OR "Q"'
      READ(5,1,END=200)ID
      IF(ID.EQ.'Z')THEN
        IN='Z'
        CALL NECDAT(NJUN)
      ELSEIF(ID.EQ.'A')THEN
        CALL BQUAD(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'B')THEN
        CALL CYLIND(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'C')THEN
        CALL CONE(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'D')THEN
        CALL DISK(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'E')THEN
        CALL SPHERE(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'G')THEN
        CALL WIRDAT
      ELSEIF(ID.EQ.'H')THEN
        CALL QUERY(BNODES,IBEDGE,IFACES,ITRAK)
      ELSEIF(ID.EQ.'I')THEN
        CALL CHANGE(BNODES,IBEDGE)
      ELSEIF(ID.EQ.'J')THEN
      IF(IN.NE.'Z')        CALL WRIOUT(BNODES,IBEDGE,NJUN)
300     CALL EOFCLR(5)
        PRINT*,'***** DEFINE TEST PARAMETERS *****'
        ID='Y'
        IF(ID.EQ.'Y')THEN
          CALL TSTDAT
        ELSEIF(ID.NE.'N')THEN
          GOTO 999
        ENDIF
        GOTO 999
      ELSEIF(ID.EQ.'K')THEN
        NBNODS=0
        NBEDGS=0
```

```
      ELSEIF(ID.EQ.'Q')THEN
        STOP
      ENDIF
      GOTO 200
 999  CONTINUE
      END
```

A.3 READIN

```
C=======================================================================
      SUBROUTINE READIN(BNODES,IBEDGE)
C=======================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
      REWIND(2)
      READ(2,*)NBNODS,NBEDGS
      DO 10 J=1,NBNODS
        READ(2,*)NODE,(BNODES(I,NODE),I=1,3)
 10   CONTINUE
      DO 20 J=1,NBEDGS
        READ(2,*)NEDGE,(IBEDGE(I,NEDGE),I=1,2)
 20   CONTINUE
      RETURN
      END
```

A.4 BQUAD

```
C=======================================================================
      SUBROUTINE BQUAD(BNODES,IBEDGE)
C=======================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*),C(3,4)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
      PRINT*,'ENTER (X,Y,Z) FOR THE 4 CORNERS IN SEQUENCE'
      DO 10 I=1,4
        PRINT*,'? CORNER ',I
 9      CALL EOFCLR(5)
        READ(5,*,END=9)C(1,I),C(2,I),C(3,I)
 10   CONTINUE
      PRINT*,'HOW MANY EDGES ALONG THE SIDE FORMED BY'
      PRINT*,'THE FIRST 2 CORNERS?'
```

```
 11   CALL EOFCLR(5)
      READ(5,*,END=11)NSEG
      N=NSEG+1
      PRINT*,'HOW MANY EDGES ALONG THE ADJACENT SIDE ?'
 21   CALL EOFCLR(5)
      READ(5,*,END=21)MSEG
      M=MSEG+1
      IF(NSEG.EQ.0 .OR. MSEG.EQ.0)RETURN
      NNODE1=NBNODS+1
      NVERTS=N*M
      ILDBNOD=NBNODS
      NBNODS=NBNODS+NVERTS
      L1=NNODE1
      L2=NNODE1+NSEG
      L3=NBNODS
      L4=NBNODS-NSEG
C
* ASSIGN THE VERTICES TO THE PROPER ARRAY ELEMENTS
C
      BNODES(1,L1)=C(1,1)
      BNODES(2,L1)=C(2,1)
      BNODES(3,L1)=C(3,1)
      BNODES(1,L2)=C(1,2)
      BNODES(2,L2)=C(2,2)
      BNODES(3,L2)=C(3,2)
      BNODES(1,L3)=C(1,3)
      BNODES(2,L3)=C(2,3)
      BNODES(3,L3)=C(3,3)
      BNODES(1,L4)=C(1,4)
      BNODES(2,L4)=C(2,4)
      BNODES(3,L4)=C(3,4)
C
* COMPUTE EDGE POINTS ALONG THE TOP AND BOTTOM.
C
      DX1=(BNODES(1,L2)-BNODES(1,L1))/NSEG
      DY1=(BNODES(2,L2)-BNODES(2,L1))/NSEG
      DZ1=(BNODES(3,L2)-BNODES(3,L1))/NSEG
      DX2=(BNODES(1,L3)-BNODES(1,L4))/NSEG
      DY2=(BNODES(2,L3)-BNODES(2,L4))/NSEG
      DZ2=(BNODES(3,L3)-BNODES(3,L4))/NSEG
      DO 30 I=1,N-2
        J=I+L1
        BNODES(1,J)=BNODES(1,L1)+I*DX1
        BNODES(2,J)=BNODES(2,L1)+I*DY1
        BNODES(3,J)=BNODES(3,L1)+I*DZ1
```

```
        J=I+L4
        BNODES(1,J)=BNODES(1,L4)+I*DX2
        BNODES(2,J)=BNODES(2,L4)+I*DY2
        BNODES(3,J)=BNODES(3,L4)+I*DZ2
 30   CONTINUE
      L41=L4-1
      L11=L1-1
C
* COMPUTE THE INNER VERTICES.
C
      DO 40 I=1,N
        J1=L41+I
        J2=L11+I
        DX=(BNODES(1,J1)-BNODES(1,J2))/MSEG
        DY=(BNODES(2,J1)-BNODES(2,J2))/MSEG
        DZ=(BNODES(3,J1)-BNODES(3,J2))/MSEG
        DO 50 J=1,M-2
          JN=J*N+J2
          BNODES(1,JN)=BNODES(1,J2)+J*DX
          BNODES(2,JN)=BNODES(2,J2)+J*DY
          BNODES(3,JN)=BNODES(3,J2)+J*DZ
 50     CONTINUE
 40   CONTINUE
      MODE=0
      CALL KNIT(IBEDGE,NNODE1,ILDBEDG,N,M,MODE)
      CALL ATTACH(BNODES,IBEDGE,ILDBNOD,ILDBEDG)
      RETURN
      END
```

A.5 CYLIND

```
C=========================================================================
      SUBROUTINE CYLIND(BNODES,IBEDGE)
C=========================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      CHARACTER*1 IDF,IDM,IDB
 1    FORMAT(A1)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
* THE FOLLOWING STATEMENT FUNCTIONS ARE FOR USE ON MACHINES
* THAT DON'T HAVE THESE EXTENTIONS TO THE INTRINSIC FUNCTIONS
C
* ENTER CENTER POINT AND ZERO DEGREE POINT ON THE CIRCUMFERENCE
```

```
* OF THE FRONT AND BACK FACE, AND ANGLE.
C
      PRINT*,'ENTER (X,Y,Z) OF THE CENTER POINT OF THE FRONT FACE'
 2    CALL EOFCLR(5)
      READ(5,*,END=2)C1X,C1Y,C1Z
      PRINT*,'ENTER (X,Y,Z) OF ZERO DEGREE POINT ON THE CIRCUMFERENCE'
      PRINT*,'OF THE FRONT FACE'
 3    CALL EOFCLR(5)
      READ(5,*,END=3)P1X,P1Y,P1Z
      PRINT*,'ENTER (X,Y,Z) OF THE CENTER POI"T OF THE BACK FACE'
 4    CALL EOFCLR(5)
      READ(5,*,END=4)C2X,C2Y,C2Z
 5    CALL EOFCLR(5)
      PRINT*,'ENTER (X,Y,Z) OF ZERO DEGREE POINT ON THE CIRCUMFERENCE'
      PRINT*,'OF THE BACK FACE'
      READ(5,*,END=5)P2X,P2Y,P2Z
 11   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES AROUND THE CIRCUMFERENCE?'
      READ(5,*,END=11)NSEG
 21   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES ALONG THE LENGTH?'
      READ(5,*,END=21)MSEG
      IF(NSEG.EQ.0 .OR. MSEG.EQ.0)RETURN
      M=MSEG+1
 31   CALL EOFCLR(5)
      PRINT*,'DO YOU WANT THE CYLINDER TO BE SLOTTED?'
      READ(5,1,END=31)IDM
      IF(IDM.EQ.'Y')THEN
        N=NSEG+1
 41     CALL EOFCLR(5)
        PRINT*,'INPUT START AND END ANGLES OF FRONT FACE'
        READ(5,*,END=41)FBGN,FEND
 51     CALL EOFCLR(5)
        PRINT*,'INPUT START AND END ANGLES OF BACK FACE'
        READ(5,*,END=51)BBGN,BEND
      ELSE
        N=NSEG
        FBGN=0.
        FEND=360.
        BBGN=0.
        BEND=360.
      ENDIF
 61   CALL EOFCLR(5)
      PRINT*,'CLOSE FRONT?'
      READ(5,1,END=61)IDF
```

```
 71   CALL EOFCLR(5)
      PRINT*,'CLOSE BACK?'
      READ(5,1,END=71)IDB
      MODE=0
      IF(IDB.EQ.'Y')MODE=MODE+1
      IF(IDM.EQ.'N')MODE=MODE+2
      IF(IDF.EQ.'Y')MODE=MODE+4
      N1=N-1
      NVERTS=N*M
      ILDBNOD=NBNODS
      NNODE1=NBNODS+1
      NBNODS=NBNODS+NVERTS
      IF(IDF.EQ.'Y')THEN
        BNODES(1,NNODE1)=C1X
        BNODES(2,NNODE1)=C1Y
        BNODES(3,NNODE1)=C1Z
        NBNODS=NBNODS+1
        NNODE1=NNODE1+1
      ENDIF
      NODBAK=NBNODS-N1
C
* U HAT=(C1-C2)/MAGNITUDE(C1-C2)
C
      CALL UNTVEC(C1X,C1Y,C1Z,C2X,C2Y,C2Z,UX,UY,UZ)
C
* PC1=P1-C1 AND PC2=P2-C2
C
      PC1X=P1X-C1X
      PC1Y=P1Y-C1Y
      PC1Z=P1Z-C1Z
      PC2X=P2X-C2X
      PC2Y=P2Y-C2Y
      PC2Z=P2Z-C2Z
C
* V1=(P1-C1)CROSS U HAT AND V2=(P2-C2)CROSS U HAT
C
      CALL XPROD(PC1X,PC1Y,PC1Z,UX,UY,UZ,V1X,V1Y,V1Z)
      CALL XPROD(PC2X,PC2Y,PC2Z,UX,UY,UZ,V2X,V2Y,V2Z)
      IF(FEND.EQ.360. .AND. FBGN.EQ.0.)THEN
        DQF=(FEND-FBGN)/N
        DQB=(BEND-BBGN)/N
      ELSE
        DQF=(FEND-FBGN)/N1
        DQB=(BEND-BBGN)/N1
      ENDIF
```

```
      DO 10 I=0,N1
        QF=I*DQF+FBGN
        QB=I*DQB+BBGN
        SINQF=SIND(QF)
        SINQB=SIND(QB)
        COSQF=COSD(QF)
        COSQB=COSD(QB)
        BNODES(1,NNODE1+I)=C1X+PC1X*COSQF+V1X*SINQF
        BNODES(2,NNODE1+I)=C1Y+PC1Y*COSQF+V1Y*SINQF
        BNODES(3,NNODE1+I)=C1Z+PC1Z*COSQF+V1Z*SINQF
        BNODES(1,NODBAK+I)=C2X+PC2X*COSQB+V2X*SINQB
        BNODES(2,NODBAK+I)=C2Y+PC2Y*COSQB+V2Y*SINQB
        BNODES(3,NODBAK+I)=C2Z+PC2Z*COSQB+V2Z*SINQB
 10   CONTINUE
C
* COMPUTE THE INNER VERTICES
C
      DO 20 I=0,N1
        DX=(BNODES(1,NODBAK+I)-BNODES(1,NNODE1+I))/MSEG
        DY=(BNODES(2,NODBAK+I)-BNODES(2,NNODE1+I))/MSEG
        DZ=(BNODES(3,NODBAK+I)-BNODES(3,NNODE1+I))/MSEG
        DO 30 J=1,M-2
          JN=J*N+NNODE1
          BNODES(1,JN+I)=BNODES(1,NNODE1+I)+J*DX
          BNODES(2,JN+I)=BNODES(2,NNODE1+I)+J*DY
          BNODES(3,JN+I)=BNODES(3,NNODE1+I)+J*DZ
 30     CONTINUE
 20   CONTINUE
      IF(IDB.EQ.'Y')THEN
        NBNODS=NBNODS+1
        BNODES(1,NBNODS)=C2X
        BNODES(2,NBNODS)=C2Y
        BNODES(3,NBNODS)=C2Z
      ENDIF
      CALL KNIT(IBEDGE,NNODE1,ILDBEDG,N,M,MODE)
      CALL ATTACH(BNODES,IBEDGE,ILDBNOD,ILDBEDG)
      RETURN
      END
```

A.6 CONE

```
C======================================================================
      SUBROUTINE CONE(BNODES,IBEDGE)
```

```
C=====================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
* THE FOLLOWING STATEMENT FUNCTIONS ARE FOR USE ON MACHINES
* THAT DON'T HAVE THESE EXTENTIONS TO THE INTRINSIC FUNCTIONS
C
 2    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF THE POINT OF THE CONE'
      READ(5,*,END=2)C2X,C2Y,C2Z
 3    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF THE CENTER POINT OF THE BASE'
      READ(5,*,END=3)C1X,C1Y,C1Z
 4    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF A POINT ON THE BACK CIRCUMFERENCE'
      READ(5,*,END=4)PX,PY,PZ
 11   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES AROUND THE CIRCUMFERENCE?'
      READ(5,*,END=11)NSEG
      N=NSEG
 12   CALL EOFCLR(5)
      PRINT*,'HOW MANY FROM THE POINT TO THE CIRCUMFERENCE?'
      READ(5,*,END=12)MSEG
      IF(NSEG.EQ.0 .OR. MSEG.EQ.0)RETURN
      N1=N-1
      NPOINT=NBNODS+1
      NNODE1=NPOINT+1
      ILDBNOD=NBNODS
      NVERTS=N*MSEG+1
      NBNODS=NBNODS+NVERTS
      NODBAK=NBNODS-N1
      BNODES(1,NPOINT)=C2X
      BNODES(2,NPOINT)=C2Y
      BNODES(3,NPOINT)=C2Z
C
*------------COMPUTE BACK POINTS------------
* U HAT=(C1-C2)/MAGNITUDE(C1-C2)
C
      CALL UNTVEC(C1X,C1Y,C1Z,C2X,C2Y,C2Z,UX,UY,UZ)
C
* PC1=P-C1
C
      PC1X=PX-C1X
      PC1Y=PY-C1Y
      PC1Z=PZ-C1Z
```

```
C
* V1= U HAT CROSS PC1
C
      CALL XPROD(UX,UY,UZ,PC1X,PC1Y,PC1Z,V1X,V1Y,V1Z)
      DQ=360./N
      DO 10 I=0,N1
        Q=I*DQ
        SINQ=SIND(Q)
        COSQ=COSD(Q)
        BNODES(1,NODBAK+I)=C1X+PC1X*COSQ+V1X*SINQ
        BNODES(2,NODBAK+I)=C1Y+PC1Y*COSQ+V1Y*SINQ
        BNODES(3,NODBAK+I)=C1Z+PC1Z*COSQ+V1Z*SINQ
 10   CONTINUE
C
*------------COMPUTE INNER VERTICES------------
C
      DO 20 I20=0,N1
        DX=(BNODES(1,NODBAK+I20)-BNODES(1,NPOINT))/MSEG
        DY=(BNODES(2,NODBAK+I20)-BNODES(2,NPOINT))/MSEG
        DZ=(BNODES(3,NODBAK+I20)-BNODES(3,NPOINT))/MSEG
        DO 30 I30=0,MSEG-1
          I=NNODE1+I30*N+I20
          I301=I30+1
          BNODES(1,I)=BNODES(1,NPOINT)+I301*DX
          BNODES(2,I)=BNODES(2,NPOINT)+I301*DY
          BNODES(3,I)=BNODES(3,NPOINT)+I301*DZ
 30     CONTINUE
 20   CONTINUE
      MODE=6
C
* ADJUST THE M DIMENSION SO THAT THE BODY LOOKS LIKE A CYLINDER
* WHEN CALLING KNIT
C
      CALL KNIT(IBEDGE,NNODE1,ILDBEDG,N,MSEG,MODE)
      CALL ATTACH(BNODES,IBEDGE,ILDBNOD,ILDBEDG)
      RETURN
      END
```

A.7 DISK

```
C======================================================================
      SUBROUTINE DISK(BNODES,IBEDGE)
C======================================================================
```

```
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
* THE FOLLOWING STATEMENT FUNCTIONS ARE FOR USE ON MACHINES
* THAT DON'T HAVE THESE EXTENTIONS TO THE INTRINSIC FUNCTIONS
C
 2    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF THE CENTER POINT OF THE DISK'
      READ(5,*,END=2)C1X,C1Y,C1Z
 3    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF A POINT ON THE CIRCUMFERENCE'
      READ(5,*,END=3)PX,PY,PZ
 4    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF A POINT PERPENDICULAR TO'
      PRINT*,'THE CENTER OF THE DISK'
      READ(5,*,END=4)C2X,C2Y,C2Z
 11   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES AROUND THE CIRCUMFERENCE?'
      READ(5,*,END=11)NSEG
      N=NSEG
 12   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES FROM THE CENTER TO THE CIRCUMFERENCE?'
      READ(5,*,END=12)MSEG
      IF(NSEG.EQ.0 .OR. MSEG.EQ.0)RETURN
      N1=N-1
      NPOINT=NBNODS+1
      NNODE1=NPOINT+1
      ILDBNOD=NBNODS
      NVERTS=N*MSEG+1
      NBNODS=NBNODS+NVERTS
      NODBAK=NBNODS-N1
      BNODES(1,NPOINT)=C1X
      BNODES(2,NPOINT)=C1Y
      BNODES(3,NPOINT)=C1Z
C
*------------COMPUTE OUTER POINTS------------
* U HAT=(C1-C2)/MAGNITUDE(C1-C2)
C
      CALL UNTVEC(C1X,C1Y,C1Z,C2X,C2Y,C2Z,UX,UY,UZ)
C
* PC1=P-C1
C
      PC1X=PX-C1X
      PC1Y=PY-C1Y
      PC1Z=PZ-C1Z
```

```
C
* V1= U HAT CROSS PC1
C
      CALL XPROD(UX,UY,UZ,PC1X,PC1Y,PC1Z,V1X,V1Y,V1Z)
      DQ=360./N
      DO 10 I=0,N1
        Q=I*DQ
        SINQ=SIND(Q)
        COSQ=COSD(Q)
        BNODES(1,NODBAK+I)=C1X+PC1X*COSQ+V1X*SINQ
        BNODES(2,NODBAK+I)=C1Y+PC1Y*COSQ+V1Y*SINQ
        BNODES(3,NODBAK+I)=C1Z+PC1Z*COSQ+V1Z*SINQ
 10   CONTINUE
C
*------------COMPUTE INNER VERTICES------------
C
      DO 20 I=0,N1
        DX=(BNODES(1,NODBAK+I)-BNODES(1,NPOINT))/MSEG
        DY=(BNODES(2,NODBAK+I)-BNODES(2,NPOINT))/MSEG
        DZ=(BNODES(3,NODBAK+I)-BNODES(3,NPOINT))/MSEG
        DO 30 J=0,MSEG-1
          INDEX=NNODE1+J*N+I
          J1=J+1
          BNODES(1,INDEX)=BNODES(1,NPOINT)+J1*DX
          BNODES(2,INDEX)=BNODES(2,NPOINT)+J1*DY
          BNODES(3,INDEX)=BNODES(3,NPOINT)+J1*DZ
 30     CONTINUE
 20   CONTINUE
      MODE=6
C
* ADJUST THE M DIMENSION SO THAT THE BODY LOOKS LIKE A CYLINDER
* WHEN CALLING KNIT
C
      CALL KNIT(IBEDGE,NNODE1,ILDBEDG,N,MSEG,MODE)
      CALL ATTACH(BNODES,IBEDGE,ILDBNOD,ILDBEDG)
      RETURN
      END
```

A.8 SPHERE

```
C============================================================
      SUBROUTINE SPHERE(BNODES,IBEDGE)
C============================================================
```

```
      DIMENSION BNODES(3,*),IBEDGE(2,*),FLEX(30)
      CHARACTER*1 ID
 1    FORMAT(A1)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
* THE FOLLOWING STATEMENT FUNCTIONS ARE FOR USE ON MACHINES
* THAT DON'T HAVE THESE EXTENTIONS TO THE INTRINSIC FUNCTIONS
C
 100  CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF THE CENTER POINT'
      READ(5,*,END=100)CX,CY,CZ
 11   CALL EOFCLR(5)
      PRINT*,'INPUT THE RADIUS'
      READ(5,*,END=11)R
 2    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF A POINT IN THE NORTH POLE DIRECTION'
      READ(5,*,END=2)PX,PY,PZ
 3    CALL EOFCLR(5)
      PRINT*,'INPUT (X,Y,Z) OF A POINT IN THE EQUATORIAL'
      PRINT*,'(0 DEGREES) DIRECTION'
      READ(5,*,END=3)EX,EY,EZ
C
* MAKE POLE AND EQUATOR DIRECTIONAL POINTS INTO UNIT VECTORS
C
      CALL UNTVEC(PX,PY,PZ,CX,CY,CZ,U1X,U1Y,U1Z)
      CALL UNTVEC(EX,EY,EZ,CX,CY,CZ,U2X,U2Y,U2Z)
C
* VERIFY THAT THEY ARE AT RIGHT ANGLES
C
      IF(ABS(U1X*U2X+U1Y*U2Y+U1Z*U2Z).GT.1E-8)THEN
        PRINT*,'YOUR CENTER, POLE, AND EQUATORIAL POINTS'
        PRINT*,'DON''T FORM A RIGHT ANGLE. PLEASE TRY AGAIN.'
        GOTO 100
      ENDIF
C
* FIND THE UNIT VECTOR THAT IS U1 CROSS U2
C
      CALL XPROD(U1X,U1Y,U1Z,U2X,U2Y,U2Z,U3X,U3Y,U3Z)
C
* THE POLE AND EQUATOR POINTS ARE THE RADIUS TIMES THE UNIT VECTORS
C
      R1X=U1X*R
      R1Y=U1Y*R
      R1Z=U1Z*R
      R2X=U2X*R
```

```
      R2Y=U2Y*R
      R2Z=U2Z*R
      R3X=U3X*R
      R3Y=U3Y*R
      R3Z=U3Z*R
C
* FIND THE START AND FINISH ANGLES OF THE LONGITUDE AND LATITUDE.
C
 12   CALL EOFCLR(5)
      PRINT*,'INPUT THE START AND FINISH ANGLES OF THE LONGITUDE'
      READ(5,*,END=12)BGNLON,ENDLON
 13   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES DOWN THE LONGITUDE?'
      READ(5,*,END=13)NSEG
 14   CALL EOFCLR(5)
      PRINT*,'INPUT THE START AND FINISH ANGLES OF THE LATITUDE'
      READ(5,*,END=14)BGNLAT,ENDLAT
 15   CALL EOFCLR(5)
      PRINT*,'HOW MANY EDGES AROUND THE LATITUDE?'
      READ(5,*,END=15)MSEG
      IF(NSEG.EQ.0 .OR. MSEG.EQ.0)RETURN
      MODE=0
      IF(ENDLON.EQ.180.)MODE=MODE+1
      IF(BGNLAT.EQ.0. .AND. ENDLAT.EQ.360.)MODE=MODE+2
      IF(BGNLON.EQ.0.)MODE=MODE+4
      NLONPT=NSEG+1
      IF(MODE.EQ.0.OR.MODE.EQ.1.OR.MODE.EQ.4.OR.MODE.EQ.5)THEN
        NLATPT=MSEG+1
      ELSE
        NLATPT=MSEG
      ENDIF
      IF(MODE.EQ.0 .OR. MODE.EQ.2)THEN
        M=NLONPT
      ELSEIF(MODE.EQ.5 .OR. MODE.EQ.7)THEN
        M=NLONPT-2
      ELSE
        M=NLONPT-1
      ENDIF
      N1=NLATPT-1
      NVERTS=NLATPT*M
      ILDBNOD=NBNODS
      NNODE1=NBNODS+1
      NBNODS=NBNODS+NVERTS
      SUMFLEX=REAL(NSEG)
      DO 30 I=1,NLONPT
```

```
        FLEX(I)=1.
30    CONTINUE
16    CALL EOFCLR(5)
      PRINT*,'DO YOU WANT UNIFORM LONGITUDINAL SEGMENT LENGTHS?'
      READ(5,1,END=16)ID
      IF(ID.EQ.'N')THEN
40      PRINT*,'ENTER THE SEGMENT NUMBER AND THE PROPORTION <0 0.>=DONE'
        READ(5,*,END=50)NUMBER,VALUE
        IF(NUMBER.NE.0)THEN
          SUMFLEX=SUMFLEX-FLEX(NUMBER)+VALUE
          FLEX(NUMBER)=VALUE
          GOTO 40
        ENDIF
50      CALL EOFCLR(5)
      ENDIF
      IF(BGNLON.EQ.0)THEN
        BNODES(1,NNODE1)=R1X
        BNODES(2,NNODE1)=R1Y
        BNODES(3,NNODE1)=R1Z
        NBNODS=NBNODS+1
        NNODE1=NNODE1+1
      ENDIF
      DTHETA=ENDLON-BGNLON
      IF(BGNLAT.EQ.0. .AND. ENDLAT.EQ.360.)THEN
        DPSI=360./NLATPT
      ELSE
        DPSI=(ENDLAT-BGNLAT)/N1
      ENDIF
      NODE=NNODE1
      THETA=BGNLON
      DO 10 LONGTU=1,NLONPT
        IF(ANINT(THETA).NE.0. .AND. ANINT(THETA).NE.180.)THEN
          SINQ=SIND(THETA)
          COSQ=COSD(THETA)
          DO 20 LATITU=0,N1
            PSI=LATITU*DPSI+BGNLAT
            SINPSI=SIND(PSI)
            COSPSI=COSD(PSI)
            BNODES(1,NODE)=R1X*COSQ+R2X*SINQ*COSPSI+R3X*SINQ*SINPSI
            BNODES(2,NODE)=R1Y*COSQ+R2Y*SINQ*COSPSI+R3Y*SINQ*SINPSI
            BNODES(3,NODE)=R1Z*COSQ+R2Z*SINQ*COSPSI+R3Z*SINQ*SINPSI
            NODE=NODE+1
20        CONTINUE
        ENDIF
        THETA=THETA+DTHETA*FLEX(LONGTU)/SUMFLEX
```

```
10    CONTINUE
      IF(ENDLON.EQ.180.)THEN
        NBNODS=NBNODS+1
        R4X=CX-(R1X-CX)
        R4Y=CY-(R1Y-CY)
        R4Z=CZ-(R1Z-CZ)
        BNODES(1,NBNODS)=R4X
        BNODES(2,NBNODS)=R4Y
        BNODES(3,NBNODS)=R4Z
      ENDIF
      CALL KNIT(IBEDGE,NNODE1,ILDBEDG,NLATPT,M,MODE)
      CALL ATTACH(BNODES,IBEDGE,ILDBNOD,ILDBEDG)
      RETURN
      END
```

A.9 KNIT

```
C=======================================================================
      SUBROUTINE KNIT(IBEDGE,NNODE1,ILDBEDG,N,M,MODE)
C=======================================================================
C
*     ALL BODIES IN THIS PROGRAM CAN BE DESCRIBED BY@D
*       1) AN OPTIONAL FRONT POINT
*       2) AN NXM BODY EITHER OPEN OR CLOSED
*       3) AN OPTIONAL BACK POINT
*
* INPUT@D
*  IBEDGE=ARRAY OF EDGES THAT EXIST SO FAR.
*  NNODE1=NUMBER OF THE FIRST NODE OF THE NXM BODY OF THIS NEW BODY.
*  N=ONE DIMENSION OF THE BODY.
*  M=THE OTHER DIMENSION OF THE BODY.
*  MODE=THE TYPE OF BODY
*          FRONT NXM BODY BACK EXAMPLE
*   MODE=0   0      0       0  QUADRANGLE, SLOTTED CYLINDER(OPEN ENDS)
*   MODE=1   0      0       1  SLOTTED CYLINDER W/CLOSED BACK
*   MODE=2   0      1       0  CYLINDER W/OPEN ENDS, SPHERE W/O POLES
*   MODE=3   0      1       1  CYLINDER W/OPEN FRONT, SPHERE W/O N POLE
*   MODE=4   1      0       0  SLOTTED CYLINDER W/CLOSED FRONT
*   MODE=5   1      0       1  SLOTTED SPHERE
*   MODE=6   1      1       0  CYLINDER W/ OPEN BACK, DISK, CONE
*   MODE=7   1      1       1  CYLINDER W/ CLOSED ENDS, SOLID SPHERE
*
* OUTPUT@D
```

```
*  IBEDGE=ARRAY WITH ALL EDGES.
*  NBEDGS=NUMBER OF ALL EDGES.
*  ILDBEDG=LAST EDGE OF LAST BODY.
C
      DIMENSION IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
      NXEDGE=NBEDGS+1
      ILDBEDG=NBEDGS
C
* COMPUTE EDGE CONNECTIONS.
* IF BACK IS CLOSED, THEN...
C
      IF(MODE.EQ.1.OR.MODE.EQ.3.OR.MODE.EQ.5.OR.MODE.EQ.7)THEN
        LASNOD=NBNODS-1
      ELSE
        LASNOD=NBNODS
      ENDIF
C
* IF FRONT IS CLOSED, THEN ADD EDGES FROM FRONT POINT TO NXM BODY.
C
      IF(MODE.GE.4)THEN
        NBEDGS=NBEDGS+N
        FRSNOD=NNODE1-1
        DO 20 I=0,N-1
          IBEDGE(1,NXEDGE)=FRSNOD
          IBEDGE(2,NXEDGE)=NNODE1+I
          NXEDGE=NXEDGE+1
 20     CONTINUE
      ENDIF
        DO 501 K=0,M-2
          J=K*N+NNODE1
C
* GO ACROSS THE N DIMENSION.
C
          DO 5001 I=0,N-2
            IBEDGE(1,NXEDGE)=I+J
            IBEDGE(2,NXEDGE)=I+J+1
            NXEDGE=NXEDGE+1
 5001     CONTINUE
C
* IF THE BODY IS CLOSED, THEN ATTACH LAST TO FIRST.
C
          IF(MODE.EQ.2.OR.MODE.EQ.3.OR.MODE.EQ.6.OR.MODE.EQ.7)THEN
            IBEDGE(1,NXEDGE)=J+N-1
```

```
            IBEDGE(2,NXEDGE)=J
            NXEDGE=NXEDGE+1
          ENDIF
C
* GO ACROSS THE MIDDLE.
C
          DO 6001 I=0,N-2
            IBEDGE(1,NXEDGE)=I+J
            IBEDGE(2,NXEDGE)=I+J+N
            NXEDGE=NXEDGE+1
            IBEDGE(1,NXEDGE)=I+J
            IBEDGE(2,NXEDGE)=I+J+N+1
            NXEDGE=NXEDGE+1
 6001     CONTINUE
C
* CLOSE THE MIDDLE
C
          IBEDGE(1,NXEDGE)=J+N-1
          IBEDGE(2,NXEDGE)=J+N-1+N
          NXEDGE=NXEDGE+1
C
* IF THE BODY IS CLOSED, THEN CLOSE LAST SLANT.
C
          IF(MODE.EQ.2.OR.MODE.EQ.3.OR.MODE.EQ.6.OR.MODE.EQ.7)THEN
            IBEDGE(1,NXEDGE)=J+N-1
            IBEDGE(2,NXEDGE)=J+N
            NXEDGE=NXEDGE+1
          ENDIF
 501    CONTINUE
C
* CLOSE THE BOTTOM.
C
        DO 41 I=LASNOD-N+1,LASNOD-1
          IBEDGE(1,NXEDGE)=I
          IBEDGE(2,NXEDGE)=I+1
          NXEDGE=NXEDGE+1
 41     CONTINUE
C
* IF BODY IS CLOSED, THEN CLOSE LAST TO FIRST.
C
        IF(MODE.EQ.2.OR.MODE.EQ.3.OR.MODE.EQ.6.OR.MODE.EQ.7)THEN
          IBEDGE(1,NXEDGE)=LASNOD
          IBEDGE(2,NXEDGE)=LASNOD-N+1
          NXEDGE=NXEDGE+1
        ENDIF
```

```
C
* IF BACK IS CLOSED, THE CONNECT LAST ROW TO BACK POINT.
C
      IF(MODE.EQ.1.OR.MODE.EQ.3.OR.MODE.EQ.5.OR.MODE.EQ.7)THEN
        NBEDGS=NBEDGS+N
        DO 21 I=0,N-1
          IBEDGE(1,NXEDGE)=NBNODS
          IBEDGE(2,NXEDGE)=NBNODS-N+I
          NXEDGE=NXEDGE+1
 21     CONTINUE
      ENDIF
      NBEDGS=NXEDGE-1
      RETURN
      END
```

A.10 ATTACH

```
C=====================================================================
      SUBROUTINE ATTACH(BNODES,IBEDGE,ILDBNOD,ILDBEDG)
C=====================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
      COMMON /SPACE/SPACE
C
* THE FOLOWING LINE IS A STATEMENT FUNCTION.
C
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
C
* FIND A COMMON NODE.
C
      DO 10 ILDPTR=1,ILDBNOD
        DO 20 NEWPTR=ILDBNOD+1,NBNODS
          XILD=BNODES(1,ILDPTR)
          YILD=BNODES(2,ILDPTR)
          ZILD=BNODES(3,ILDPTR)
          XNEW=BNODES(1,NEWPTR)
          YNEW=BNODES(2,NEWPTR)
          ZNEW=BNODES(3,NEWPTR)
C
* IF IT IS A COMMON NODE...
C
          IF(SIZE(XILD-XNEW,YILD-YNEW,ZILD-ZNEW).LE.SPACE)THEN
            NBNODS=NBNODS-1
```

```
C
* LOOP THROUGH ALL THE EDGES
C
            DO 50 I=ILDBEDG+1,NBEDGS
C
* AND CHANGE ANY THAT HAVE THE NEWEST NODE TO THE OLDER NODE
C
              IF(IBEDGE(1,I).EQ.NEWPTR)THEN
                IBEDGE(1,I)=ILDPTR
              ELSEIF(IBEDGE(2,I).EQ.NEWPTR)THEN
                IBEDGE(2,I)=ILDPTR
              ENDIF
C
* AND DECREASE ANY WITH BIGGER NODE NUMBERS BY ONE.
C
              IF(IBEDGE(1,I).GT.NEWPTR)IBEDGE(1,I)=IBEDGE(1,I)-1
              IF(IBEDGE(2,I).GT.NEWPTR)IBEDGE(2,I)=IBEDGE(2,I)-1
 50         CONTINUE
C
* DECREASE BIGGER NODE NUMBERS BY ONE.
C
            DO 60 I=NEWPTR,NBNODS
              BNODES(1,I)=BNODES(1,I+1)
              BNODES(2,I)=BNODES(2,I+1)
              BNODES(3,I)=BNODES(3,I+1)
 60         CONTINUE
            GOTO 10
          ENDIF
 20     CONTINUE
 10   CONTINUE
C
* FIND A COMMON EDGE
C
      DO 30 ILDPTR=1,ILDBEDG
        DO 40 NEWPTR=ILDBEDG+1,NBEDGS
C
* IF IT IS A COMMON EDGE
C
          I1=IBEDGE(1,ILDPTR)
          I2=IBEDGE(2,ILDPTR)
          N1=IBEDGE(1,NEWPTR)
          N2=IBEDGE(2,NEWPTR)
          IF((I1.EQ.N1.AND.I2.EQ.N2).OR.(I1.EQ.N2.AND.I2.EQ.N1))THEN
C
* THEN DELETE THE NEW EDGE BY DECREASING THE REMAINING EDGE NUMBERS
```

```
C
          NBEDGS=NBEDGS-1
          DO 35 I=NEWPTR,NBEDGS
            IBEDGE(1,I)=IBEDGE(1,I+1)
            IBEDGE(2,I)=IBEDGE(2,I+1)
 35       CONTINUE
          GOTO 30
        ENDIF
 40   CONTINUE
 30   CONTINUE
      RETURN
      END
```

A.11 QUERY

```
C======================================================================
      SUBROUTINE QUERY(BNODES,IBEDGE,IFACES,ITRAK)
C======================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*),IFACES(3,*),ITRAK(*)
      CHARACTER*1 ID
 1    FORMAT(A1)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
      ITIME=0
 100  CALL EOFCLR(5)
      PRINT*,'INFORMATION ON A NODE, EDGE, OR FACE?'
      PRINT*,'INPUT "N" OR "E" OR "F" OR "Q"'
      READ(5,1,END=100)ID
      IF(ID.EQ.'N')THEN
 12     CALL EOFCLR(5)
        PRINT*,'ENTER NODE NUMBER'
        READ(5,*,END=12)ND
        IF(ND.LE.NBNODS)THEN
          X=BNODES(1,ND)
          Y=BNODES(2,ND)
          Z=BNODES(3,ND)
          PRINT*,'NODE ',ND,' IS AT (',X,',',Y,',',Z,')'
          DO 10 IPOINT=1,NBEDGS
            IF(IBEDGE(1,IPOINT).EQ.ND .OR. IBEDGE(2,IPOINT).EQ.ND)
     >        PRINT*,'EDGE ',IPOINT,' IS CONNECTED TO IT'
 10       CONTINUE
        ELSE
          PRINT*,'NODE ',ND,' DOES NOT EXIST.'
```

```
        ENDIF
      ELSEIF(ID.EQ.'E')THEN
 11     CALL EOFCLR(5)
        PRINT*,'ENTER EDGE NUMBER'
        READ(5,*,END=11)IEN
        IF(IEN.LE.NBEDGS)THEN
          IFROM=IBEDGE(1,IEN)
          ITO=IBEDGE(2,IEN)
          PRINT*,'EDGE ',IEN,' GOES FROM NODE ',IFROM,' TO NODE ',ITO
        ELSE
          PRINT*,'EDGE ',IEN,' DOES NOT EXIST.'
        ENDIF
      ELSEIF(ID.EQ.'F')THEN
 13     CALL EOFCLR(5)
        PRINT*,'ENTER FACE NUMBER'
        READ(5,*,END=13)IFAC
        IF(IFAC.LE.NFACES)THEN
          ITIME=ITIME+1
          IF(ITIME.EQ.1)CALL FAEMUL(IBEDGE,IFACES,ITRAK,2)
          IONE=IFACES(1,IFAC)
          ITWO=IFACES(2,IFAC)
          ITHREE=IFACES(3,IFAC)
          PRINT*,'FACE ',IFAC,' HAS EDGES ',IONE,ITWO,ITHREE
        ELSE
          PRINT*,'FACE ',IFAC,' DOES NOT EXIST '
        ENDIF
      ELSEIF(ID.EQ.'Q')THEN
        RETURN
      ENDIF
      GOTO 100
      END
```

A.12 CHANGE

```
C======================================================================
      SUBROUTINE CHANGE(BNODES,IBEDGE)
C======================================================================
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      CHARACTER*1 ID
  1   FORMAT(A1)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
 100  CALL EOFCLR(5)
```

```
      PRINT*,'DO YOU WANT TO ADD, DELETE, OR MOVE'
      PRINT*,'INPUT "A", "D", "M", OR "Q"'
      READ(5,1,END=100)ID
      IF(ID.EQ.'A')THEN
200     CALL EOFCLR(5)
        PRINT*,'DO YOU WISH TO ADD A NODE OR INSERT EDGE?'
        PRINT*,'INPUT "N", "E", OR "Q"'
        READ(5,1,END=200)ID
        IF(ID.EQ.'N')THEN
          NBNODS=NBNODS+1
11        CALL EOFCLR(5)
          PRINT*,'INPUT (X,Y,Z) FOR NODE ',NBNODS
          READ(5,*,END=11)X,Y,Z
          BNODES(1,NBNODS)=X
          BNODES(2,NBNODS)=Y
          BNODES(3,NBNODS)=Z
        ELSEIF(ID.EQ.'E')THEN
12        CALL EOFCLR(5)
          PRINT*,'INPUT EDGE NUMBER AND "FROM" AND "TO" NODES'
          READ(5,*,END=12)IEDGE,IFROM,ITO
          NBEDGS=NBEDGS+1
          DO 50 I=NBEDGS,IEDGE+1,-1
            IBEDGE(1,I)=IBEDGE(1,I-1)
            IBEDGE(2,I)=IBEDGE(2,I-1)
50        CONTINUE
          IBEDGE(1,IEDGE)=IFROM
          IBEDGE(2,IEDGE)=ITO
        ELSEIF(ID.EQ.'Q')THEN
          GOTO 999
        ELSE
          GOTO 200
        ENDIF
      ELSEIF(ID.EQ.'D')THEN
300     CALL EOFCLR(5)
        PRINT*,'DELETE NODES OR EDGES?'
        PRINT*,'INPUT "N", "E", OR "Q"'
        READ(5,1,END=300)ID
        IF(ID.EQ.'N')THEN
13        CALL EOFCLR(5)
          PRINT*,'INPUT RANGE OF NODE NUMBERS'
          READ(5,*,END=13)ND1,ND2
          DO 60 ND=ND2,ND1,-1
            IF(ND.LE.NBNODS)THEN
              NBNODS=NBNODS-1
              DO 20 I=ND,NBNODS
```

```
            BNODES(1,I)=BNODES(1,I+1)
            BNODES(2,I)=BNODES(2,I+1)
            BNODES(3,I)=BNODES(3,I+1)
20        CONTINUE
          ISTART=1
          KILLED=0
400       DO 30 I=ISTART,NBEDGS
            IF(IBEDGE(1,I+KILLED).EQ.ND
     >      .OR.IBEDGE(2,I+KILLED).EQ.ND)THEN
              KILLED=KILLED+1
              NBEDGS=NBEDGS-1
              ISTART=I
              GOTO 400
            ENDIF
            IBEDGE(1,I)=IBEDGE(1,I+KILLED)
            IBEDGE(2,I)=IBEDGE(2,I+KILLED)
30        CONTINUE
          DO 40 I=1,NBEDGS
            IF(IBEDGE(1,I).GT.ND)IBEDGE(1,I)=IBEDGE(1,I)-1
            IF(IBEDGE(2,I).GT.ND)IBEDGE(2,I)=IBEDGE(2,I)-1
40        CONTINUE
        ELSE
          PRINT*,'NODE ',ND,' DOES NOT EXIST'
        ENDIF
60    CONTINUE
    ELSEIF(ID.EQ.'E')THEN
14    CALL EOFCLR(5)
      PRINT*,'INPUT EDGE NUMBER'
      READ(5,*,END=14)IEN
      IF(IEN.LE.NBEDGS)THEN
        NBEDGS=NBEDGS-1
        DO 10 I=IEN,NBEDGS
          IBEDGE(1,I)=IBEDGE(1,I+1)
          IBEDGE(2,I)=IBEDGE(2,I+1)
10      CONTINUE
      ELSE
        PRINT*,'EDGE ',IEN,' DOES NOT EXIST'
      ENDIF
    ELSEIF(ID.EQ.'Q')THEN
      GOTO 999
    ELSE
      GOTO 300
    ENDIF
  ELSEIF(ID.EQ.'M')THEN
15  CALL EOFCLR(5)
```

```
      PRINT*,'WHICH NODE?'
      READ(5,*,END=15)ND
      IF(ND.LE.NBNODS)THEN
        X=BNODES(1,ND)
        Y=BNODES(2,ND)
        Z=BNODES(3,ND)
16      CALL EOFCLR(5)
        PRINT*,'NODE ',ND,' IS AT (',X,',',Y,',',Z,')'
        PRINT*,'DO YOU WANT TO ENTER (X,Y,Z) OR NODE NUMBER?'
        PRINT*,'ENTER "X" OR "N"'
        READ(5,1,END=16)ID
        IF(ID.EQ.'X')THEN
2         CALL EOFCLR(5)
          PRINT*,'INPUT NEW (X,Y,Z)'
          READ(5,*,END=2)X,Y,Z
          BNODES(1,ND)=X
          BNODES(2,ND)=Y
          BNODES(3,ND)=Z
        ELSE
17        CALL EOFCLR(5)
          PRINT*,'INPUT NODE NUMBER'
          READ(5,*,END=17)NDOLD
          BNODES(1,ND)=BNODES(1,NDOLD)
          BNODES(2,ND)=BNODES(2,NDOLD)
          BNODES(3,ND)=BNODES(3,NDOLD)
        ENDIF
      ELSE
        PRINT*,'NODE ',ND,' DOES NOT EXIST'
      ENDIF
    ELSEIF(ID.EQ.'Q')THEN
      GOTO 999
    ENDIF
    GOTO 100
999 CONTINUE
    CALL PACKIT(BNODES,IBEDGE)
    RETURN
    END
```

A.13 PACKIT

```
C======================================================================
      SUBROUTINE PACKIT(BNODES,IBEDGE)
C======================================================================
```

```
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
      COMMON /SPACE/SPACE
C
* THE FOLLOWING LINE IS A STATEMENT FUNCTION.
C
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
C
* FIND A COMMON NODE.
C
      DO 10 ILDPTR=1,NBNODS-1
        DO 20 NEWPTR=ILDPTR+1,NBNODS
          XILD=BNODES(1,ILDPTR)
          YILD=BNODES(2,ILDPTR)
          ZILD=BNODES(3,ILDPTR)
          XNEW=BNODES(1,NEWPTR)
          YNEW=BNODES(2,NEWPTR)
          ZNEW=BNODES(3,NEWPTR)
C
* IF IT IS A COMMON NODE...
C
          IF(SIZE(XILD-XNEW,YILD-YNEW,ZILD-ZNEW).LE.SPACE)THEN
            NBNODS=NBNODS-1
C
* LOOP THROUGH ALL THE EDGES
C
            DO 50 I=1,NBEDGS
C
* AND CHANGE ANY THAT HAVE THE NEWEST NODE TO THE OLDER NODE
C
              IF(IBEDGE(1,I).EQ.NEWPTR)THEN
                IBEDGE(1,I)=ILDPTR
              ELSEIF(IBEDGE(2,I).EQ.NEWPTR)THEN
                IBEDGE(2,I)=ILDPTR
              ENDIF
C
* AND DECREASE ANY WITH BIGGER NODE NUMBERS BY ONE.
C
              IF(IBEDGE(1,I).GT.NEWPTR)IBEDGE(1,I)=IBEDGE(1,I)-1
              IF(IBEDGE(2,I).GT.NEWPTR)IBEDGE(2,I)=IBEDGE(2,I)-1
 50         CONTINUE
C
* DECREASE BIGGER NODE NUMBERS BY ONE.
C
            DO 60 I=NEWPTR,NBNODS
```

```
            BNODES(1,I)=BNODES(1,I+1)
            BNODES(2,I)=BNODES(2,I+1)
            BNODES(3,I)=BNODES(3,I+1)
 60       CONTINUE
          GOTO 10
        ENDIF
 20     CONTINUE
 10   CONTINUE
C
* FIND A COMMON EDGE
C
      DO 30 ILDPTR=1,NBEDGS-1
        DO 40 NEWPTR=ILDPTR+1,NBEDGS
C
* IF IT IS A COMMON EDGE
C
          IF((IBEDGE(1,ILDPTR).EQ.IBEDGE(1,NEWPTR).AND.IBEDGE(2,ILDPTR).
     >EQ.IBEDGE(2,NEWPTR)).OR.(IBEDGE(1,ILDPTR).EQ.IBEDGE(2,NEWPTR).AND.
     >IBEDGE(2,ILDPTR).EQ.IBEDGE(1,NEWPTR)))THEN
C
* THEN DELETE THE NEW EDGE BY DECREASING THE REMAINING EDGE NUMBERS
C
            NBEDGS=NBEDGS-1
            DO 35 I=NEWPTR,NBEDGS
              IBEDGE(1,I)=IBEDGE(1,I+1)
              IBEDGE(2,I)=IBEDGE(2,I+1)
 35         CONTINUE
            GOTO 30
          ENDIF
 40     CONTINUE
 30   CONTINUE
      RETURN
      END
```

A.14 WRIOUT

```
C=====================================================================
      SUBROUTINE WRIOUT(BNODES,IBEDGE,NJUN)
C=====================================================================
      CHARACTER*10 NAME
      DIMENSION BNODES(3,*),IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
```

```
      NAME='FOR002.DAT'
 4    CALL EOFCLR(5)
 3    FORMAT(A10)
      OPEN(6,FILE=NAME,TYPE='NEW')
      REWIND(6)
      IF(NJUN.LE.0)THEN
      NJCT=NJUN
      NJUN=1
      ELSE
      NJCT=1
      ENDIF
      WRITE(6,1)NJCT,NJUN
      WRITE(6,1)NBNODS,NBEDGS
 1    FORMAT(3I5)
      DO 10 J=1,NBNODS
        WRITE(6,2)J,(BNODES(I,J),I=1,3)
 10   CONTINUE
 2    FORMAT(I5,1P3E22.14)
      DO 20 J=1,NBEDGS
        WRITE(6,1)J,(IBEDGE(I,J),I=1,2)
 20   CONTINUE
      RETURN
      END
```

A.15 TSTDAT

```
C======================================================================
      SUBROUTINE TSTDAT
C======================================================================
      PARAMETER(MXFLD=10,MXEXCI=10)
      CHARACTER*1 ID
 1    FORMAT(A1)
      INTEGER IGNDP(3)
      LOGICAL PRINTC,THEV
      REAL RFIELD(3,MXFLD)
C
 11   CALL EOFCLR(5)
      PRINT*,'ENTER THE NUMBER OF SYMMETRY PLANES'
 15   CALL EOFCLR(5)
      READ(5,*,END=15)NGNDP
      IF(NGNDP.EQ.0)THEN
        IGNDP(1)=0
        IGNDP(2)=0
```

```
        IGNDP(3)=0
      ELSEIF(NGNDP.GE.1.AND.NGNDP.LE.3)THEN
        PRINT*,'ENTER SYMMETRY PLANE TYPE AT X=0'
        PRINT*,'  -1 IF THERE IS A P.E.C'
        PRINT*,'   0 IF NO IMAGE PLANE'
        PRINT*,'  +1 IF THERE IS A P.M.C'
 16     CALL EOFCLR(5)
        READ(5,*,END=16)IGNDP(1)
        PRINT*,'ENTER SYMMETRY PLANE TYPE AT Y=0'
 116     CALL EOFCLR(5)
        READ(5,*,END=116)IGNDP(2)
        PRINT*,'ENTER SYMMETRY PLANE TYPE AT Z=0'
 216     CALL EOFCLR(5)
        READ(5,*,END=216)IGNDP(3)
      ELSE
        GOTO 15
      ENDIF
 17   CALL EOFCLR(5)
          WRITE(6,*)NGNDP
          WRITE(6,*)(IGNDP(I),I=1,3)
C
* PRINTC AND THEV ARE WRITTEN EXPLICITLY AS  .TRUE.  OR  .FALSE.
* BECAUSE PATCH MAY BE RUN ON A DIFFERENT MACHINE THAN BUILD.
* FOR INSTANCE, IF BUILD WERE RUN ON A VAX, THE OUTPUT OF THEV
* IF THEV WERE FALSE WOULD BE F BUT IF PATCH WERE RUN ON A CRAY,
* THE CRAY WOULD NEED A DECIMAL POINT BEFORE THE F
C
 21   CALL EOFCLR(5)
      PRINT*,'INPUT IPAT;0 IF NO FAR FIELD,1 OR 2 IF FAR FIELD'
      PRINT*,'IPAT=1 IF A 3 POINT QUADRATURE IS USED'
      PRINT*,'IPAT=2 IF A 1 POINT QUADRATURE IS USED'
      READ(5,*)IPAT
      WRITE(6,*)IPAT
      IF(IPAT.NE.0)THEN
      PRINT*,'INPUT:PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA (DEG)'
      READ(5,*)PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA
      WRITE(6,*)PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA
      ENDIF
      PRINT*,'INPUT ITOT;=0 IF NO CHARGE DENSITY'
      PRINT*,'ITOT;=1 IF CHARGE DENSITY COMPUTATION IS DESIRED'
      READ(5,*)ITOT
      WRITE(6,*)ITOT
        NEXCIT=1
      DO 30 I=1,NEXCIT
        PRINT*,'EXCITATION IS PLANE WAVE, OR VOLTAGE?'
```

```
       PRINT*,'TYPE IN "P", OR "V"'
 222      CALL EOFCLR(5)
       READ(5,1,END=222)ID
       WRITE(6,'(1X,A1)')ID
       IF(ID.NE.'V')THEN
         PRINT*,'INPUT THETA, PHI, REAL AND IMAG OF HTHETA,'
         PRINT*,'REAL AND IMAG OF HPHI'
 22      CALL EOFCLR(5)
         READ(5,*,END=22)THETA,PHI,RHTHET,CHTHET,RHPHI,CHPHI
         WRITE(6,'(6(E12.5))')THETA,PHI,RHTHET,CHTHET,RHPHI,CHPHI
       ELSEIF(ID.NE.'P')THEN
       WRITE(8,'(1X,A1)')ID
         PRINT*,'NUMBER OF VOLTAGE SOURCES ON THE WIRE'
 122      CALL EOFCLR(5)
         READ(5,*,END=122)NVOLT
         WRITE(6,*)NVOLT
         WRITE(8,*)NVOLT
         DO 5000 III=1,NVOLT
          PRINT*,'DELTA GAP VOLTAGE ON WHICH NODE OF THE WIRE?'
 123      CALL EOFCLR(5)
          READ(5,*,END=123)NODV
          PRINT*,'VOLTAGE = ? IN COMPLEX FORM, REAL(V), IMAG(V)'
 124      CALL EOFCLR(5)
          READ(5,*,END=124)RV,XV
          WRITE(6,*)NODV,RV,XV
          WRITE(8,*)NODV,RV,XV
 5000    CONTINUE
       ENDIF
 30   CONTINUE
C
 40   CONTINUE
       PRINT*,'ENTER FREQUENCIES, -1 WHEN DONE'
 125      CALL EOFCLR(5)
       READ(5,*,END=125)FREQ
       WRITE(6,*)FREQ
       IF(FREQ.NE.-1)GO TO 40
 99   CONTINUE
      CLOSE(UNIT=6,DISPOSE='SAVE')
      CLOSE(UNIT=8,DISPOSE='SAVE')
      RETURN
      END
```

A.16 XPROD

```
C=======================================================================
      SUBROUTINE XPROD(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3)
C=======================================================================
      X3=Y1*Z2-Y2*Z1
      Y3=X2*Z1-X1*Z2
      Z3=X1*Y2-X2*Y1
      RETURN
      END
```

A.17 UNTVEC

```
C=======================================================================
      SUBROUTINE UNTVEC(X1,Y1,Z1,X2,Y2,Z2,UX,UY,UZ)
C=======================================================================
      UX=X1-X2
      UY=Y1-Y2
      UZ=Z1-Z2
      SIZE=SQRT(UX*UX+UY*UY+UZ*UZ)
      UX=UX/SIZE
      UY=UY/SIZE
      UZ=UZ/SIZE
      RETURN
      END
```

A.18 FAEMUL

```
C=======================================================================
      SUBROUTINE FAEMUL(IBEDGE,IFACES,ITRAK,IFLAG)
C=======================================================================
C
* IF IFLAG=1
* THIS SUBROUTINE FILLS IFACES WITH THE NODE NUMBERS THAT FORM THE FACE.
* IF IFLAG=2
* THIS SUBROUTINE FILLS IFACES WITH THE EDGE NUMBERS THAT FORM THE FACE.
* IT RETURNS THE NUMBER OF FACES(NFACES). ITRAK IS A WORK ARRAY.
C
      INTEGER IBEDGE(2,*),IFACES(3,*),ITRAK(*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
```

```
      NFACES=0
C
* FIND FACES AND LIST THEM IN IFACES.
C
      DO 100 IEDGE=1,NBEDGS-2
        NTRAK=0
C
* LOOK FOR ALL EDGES THAT ATTACH TO EDGE IEDGE AND PUT THEM IN ITRAK.
C
        DO 200 JEDGE=IEDGE+1,NBEDGS
          DO 20 I=1,2
            DO 21 J=1,2
              IF(IBEDGE(I,IEDGE).EQ.IBEDGE(J,JEDGE))THEN
C
* WE HAVE FOUND AN EDGE
C
                NTRAK=NTRAK+1
                ITRAK(NTRAK)=JEDGE
                GOTO 200
              ENDIF
 21         CONTINUE
 20       CONTINUE
 200    CONTINUE
C
* FIND ALL PAIRS OF EDGES THAT FORM A FACE WITH IEDGE.
C
        DO 300 JEDGE=1,NTRAK-1
          DO 301 KEDGE=JEDGE+1,NTRAK
            DO 30 J=1,2
              DO 31 K=1,2
C
* IF THE 2 EDGES IN ITRAK HAVE A COMMON POINT AND
* THE COMMON POINT IS NOT IN COMMON WITH THE IEDGE...
C
                IF((IBEDGE(J,ITRAK(JEDGE)).EQ.IBEDGE(K,ITRAK(KEDGE)))
     >.AND.(IBEDGE(J,ITRAK(JEDGE)).NE.IBEDGE(1,IEDGE)
     >.AND.IBEDGE(J,ITRAK(JEDGE)).NE.IBEDGE(2,IEDGE)))THEN
C
* THEN WE HAVE FOUND A FACE.
C
                  NFACES=NFACES+1
                  IF(IFLAG.EQ.1)THEN
C
* PUT THE NODES INTO IFACES
C
```

```
                  CALL BFACVT(IBEDGE,IEDGE,ITRAK(JEDGE),ITRAK(KEDGE),
     >            NODE1,NODE2,NODE3)
                  IFACES(1,NFACES)=NODE1
                  IFACES(2,NFACES)=NODE2
                  IFACES(3,NFACES)=NODE3
                ELSE
C
* PUT THE EDGES INTO IFACES.
C
                  IFACES(1,NFACES)=IEDGE
                  IFACES(2,NFACES)=ITRAK(JEDGE)
                  IFACES(3,NFACES)=ITRAK(KEDGE)
                ENDIF
                GOTO 300
              ENDIF
 31         CONTINUE
 30       CONTINUE
 301    CONTINUE
 300  CONTINUE
 100  CONTINUE
      RETURN
      END
```

A.19 BFACVT

```
C=====================================================================
      SUBROUTINE BFACVT(IBEDGE,IE1,IE2,IE3,NV1,NV2,NV3)
C=====================================================================
C
* NV1 IS NODE OPPOSITE EDGE IE1.
* NV2 IS NODE OPPOSITE EDGE IE2.
* NV3 IS NODE OPPOSITE EDGE IE3.
C
      INTEGER IBEDGE(2,*)
      COMMON /BODY/NBNODS,NBEDGS,NFACES
C
* THE NODE NV1 IS THE NODE THAT EDGES 2 AND 3 HAVE IN COMMON
C
      IF(IBEDGE(1,IE2).EQ.IBEDGE(1,IE3).OR.IBEDGE(1,IE2).EQ.IBEDGE(2,IE3
     >))THEN
        NV1=IBEDGE(1,IE2)
      ELSE
        NV1=IBEDGE(2,IE2)
```

```
      ENDIF
C
* THE NODE NV2 IS THE NODE THAT EDGES 1 AND 3 HAVE IN COMMON.
C
      IF(IBEDGE(1,IE1).EQ.IBEDGE(1,IE3).OR.IBEDGE(1,IE1).EQ.IBEDGE(2,IE3
     >))THEN
        NV2=IBEDGE(1,IE1)
      ELSE
        NV2=IBEDGE(2,IE1)
      ENDIF
C
* THE NODE NV3 IS THE NODE THAT EDGES 1 AND 2 HAVE IN COMMON.
C
      IF(IBEDGE(1,IE1).EQ.IBEDGE(1,IE2).OR.IBEDGE(1,IE1).EQ.IBEDGE(2,IE2
     >))THEN
        NV3=IBEDGE(1,IE1)
      ELSE
        NV3=IBEDGE(2,IE1)
      ENDIF
      RETURN
      END
```

A.20 EOFCLR

```
C=====================================================================
      SUBROUTINE EOFCLR(I)
C=====================================================================
* THIS ROUTINE CLEARS AN END-OF-FILE. IT IS USED TO PREVENT THE USER
* FROM BEING BOMBED OFF IF A <CR> IS HIT BY ACCIDENT.
C
      REWIND(I)
      RETURN
      END
```

A.21 WIRDAT

```
C=================================================================
        SUBROUTINE WIRDAT
C-----------------------------------------------------------------
C THIS ROUTINE CREATES INPUT DATA OF A STRAIGHT WIRE FOR JUNGRD CODE
C-----------------------------------------------------------------
```

```
      REAL SH(3)
      WRITE(6,*)'THE COORDINATES OF THE END POINT OF THE WIRE?'
      WRITE(6,*)'X,Y,Z IN RECTANGULAR COORDINATE SYSTEM'
 1     CALL EOFCLR(5)
      READ(5,*,END=1)X1,Y1,Z1
      WRITE(6,*)'THE COORDINATES OF THE OTHER END POINT OF THE WIRE?'
      WRITE(6,*)'X,Y,Z IN RECTANGULAR COORDINATE SYSTEM'
 2     CALL EOFCLR(5)
      READ(5,*,END=2)X2,Y2,Z2
      WRITE(6,*)'HOW MANY SEGMENTS ON THE WIRE?'
 3     CALL EOFCLR(5)
      READ(5,*,END=3)NSEG
      WRITE(6,*)'RADIUS OF WIRE = ?'
 4     CALL EOFCLR(5)
      READ(5,*,END=4)RWIRE
      NODE=NSEG+1
      WRITE(8,*) NODE,NSEG
      SH(1)=X2-X1
      SH(2)=Y2-Y1
      SH(3)=Z2-Z1
      S=SQRT(SH(1)*SH(1)+SH(2)*SH(2)+SH(3)*SH(3))
      DO 400 J=1,3
400   SH(J)=SH(J)/S
      DEL=S/NSEG
      DO N=1,NODE
      DL=DEL*(N-1)
      X=X1+DL*SH(1)
      Y=Y1+DL*SH(2)
      Z=Z1+DL*SH(3)
      WRITE(8,*)N,X,Y,Z
      END DO
      DO NS=1,NSEG
      WRITE(8,*)NS,NS,NS+1,RWIRE
      END DO
      RETURN
      END
```

A.22 NECDAT

```
C==================================================================
      SUBROUTINE NECDAT(NJUN)
C------------------------------------------------------------------
C THIS SUBROUTINE READ EXISTING NEC FORMATED DATA FILE
```

```
C AND TRANSLATE TO JUNCTION FORMATED INPUT DATA FILES
C
        PARAMETER(MXEDGS=1500,MXWNOD=1500)
        INTEGER NCON(2,MXEDGS),NN(3),NED(3,3)
        REAL DAT(3,MXEDGS),X(3),Y(3),Z(3)
     &  ,WNODE(3,MXWNOD),SH(3)
        CHARACTER FILENAME*15,TAG(MXEDGS)*2,AA*2,NAME*15
10      FORMAT(A)
        PRINT*,'WHAT IS THE FILENAME OF NEC FORMAT DATA FILE?'
 1       CALL EOFCLR(5)
        READ(5,10,END=1)FILENAME
        OPEN(10,FILE=FILENAME,STATUS='OLD')
        REWIND(10)
        NAME='FOR002.DAT'
   4    CALL EOFCLR(5)
 3    FORMAT(A10)
      OPEN(6,FILE=NAME,TYPE='NEW')
      REWIND(6)
      IF(NJUN.LE.0)THEN
      NJCT=NJUN
      NJUN=1
      ELSE
      NJCT=1
      ENDIF
      WRITE(6,*)NJCT,NJUN
C
C READ INPUT DATA FILE
C
        DO 500 N=1,MXEDGS
500     READ(10,11,END=600)TAG(N)
11      FORMAT(A2)
600     LINE=N
        REWIND(10)
        NODE=0
        NEDG=0
        DO 700 NL=1,LINE
C
C READ THE COORDINATES OF THE THREE VERTICES OF THE TRIANGLE
C
        IF(TAG(NL).EQ.'SP')THEN
        READ(10,112)AA,X(1),Y(1),Z(1),X(2),Y(2),Z(2)
112     FORMAT(A2,8X,6F10.4)
        READ(10,113)AA,X(3),Y(3),Z(3)
113     FORMAT(A2,8X,3F10.4)
C
```

```
C DISCARD DUPLICATE NODES
C
        DO 50 I=1,3
        DO 20 N=1,NODE
20      IF(DAT(1,N).EQ.X(I).AND.DAT(2,N).EQ.Y(I).
     &  AND.DAT(3,N).EQ.Z(I)) GO TO 30
        NODE=NODE+1
        NN(I)=NODE
        DAT(1,NN(I))=X(I)
        DAT(2,NN(I))=Y(I)
        DAT(3,NN(I))=Z(I)
30      NN(I)=  N
50      CONTINUE
C
C DISCARD DUPLICATE EDGES
C
        DO 60 I=1,3
        I1=I+1
        IF(I1.EQ.4)I1=1
        NED(1,I)=NN(I)
60      NED(2,I)=NN(I1)
        DO 70 I=1,3
        DO 80 NE=1,NEDG
80      IF((NCON(1,NE).EQ.NED(1,I).AND.NCON(2,NE).EQ.NED(2,I)).OR.
     &  (NCON(1,NE).EQ.NED(2,I).AND.NCON(2,NE).EQ.NED(1,I))) GO TO 70
        NEDG=NEDG+1
        NNE=NEDG
        NCON(1,NNE)=NED(1,I)
        NCON(2,NNE)=NED(2,I)
70      CONTINUE
        ENDIF
C
C READ THE TOTAL SUBSEGMENT NUMBER OF THE WIRE
C READ THE COORDINATES OF THE START AND END POINTS OF THE WIRE
C
        IF(TAG(NL).EQ.'GW')THEN
        READ(10,800)AA,ITG,NWSEG,WNODE(1,1),WNODE(2,1),WNODE(3,1)
     $  ,WNODE(1,NWSEG+1),WNODE(2,NWSEG+1),WNODE(3,NWSEG+1),RAD
800     FORMAT(A2,I3,I5,7F10.4)
        ENDIF
700     CONTINUE
C
C TRANSFER NEC FORMAT DATA TO OUR FORMAT DATA
C
        WRITE(6,*)NODE,NEDG
```

```
      DO 100 I=1,NODE
100   WRITE(6,*)I,DAT(1,I),DAT(2,I),DAT(3,I)
      DO 200 I=1,NEDG
200   WRITE(6,*)I,NCON(1,I),NCON(2,I)
      SH(1)=WNODE(1,NWSEG+1)-WNODE(1,1)
      SH(2)=WNODE(2,NWSEG+1)-WNODE(2,1)
      SH(3)=WNODE(3,NWSEG+1)-WNODE(3,1)
      S=SQRT(SH(1)*SH(1)+SH(2)*SH(2)+SH(3)*SH(3))
      DO 400 J=1,3
400   SH(J)=SH(J)/S
      DEL=S/NWSEG
      DO 900 J=1,3
      DO 900 N=1,NWSEG
900   WNODE(J,N+1)=WNODE(J,1)+DEL*SH(J)*N
      WRITE(8,*)NWSEG+1,NWSEG
      DO 300 I=1,NWSEG+1
300   WRITE(8,*)I,WNODE(1,I),WNODE(2,I),WNODE(3,I)
      DO 1000 I=1,NWSEG
1000  WRITE(8,*)I,I,I+1,RAD
      RETURN
      END
```

A.23 BODIN

```
C======================================================================
      SUBROUTINE BODIN(MXBDND,MXEDGS,DATNOD,NCONN,NNODES,
     $NEDGES,MXEXCI,EXCITF,NEXCIT,NJCT,MNJUN,MXWVLT,NWVLT,
     $NODVLT,CWVLT,IPAT,ITOT)
C----------------------------------------------------------------------
C THIS SUBROUTINE SETS CONSTANTS FOR COMMON/MEDIUM/. THEN IT READS
C TWO SETS OF INPUT DATA DEFINING THE BODY OR BODIES.
C THE FIRST SET OF DATA CONTAINS NODE NUMBERS
C AND THEIR COORDINATES. EACH NODE ALONG WITH ITS THREE COORDINATES
C IS READ AND STORED IN THE MATRIX DATNOD.
C THE SECOND SET OF DATA CONTAINS EDGE NUMBERS AND
C THE NODES TO WHICH EACH PARTICULAR EDGE IS CONNECTED. THIS
C INFORMATION IS STORED IN THE MATRIX NCONN.
C NCONN(3,EDGE)=-1 BECAUSE THE MULTIPLICITY
C FACTOR IS THE NUMBER OF ATTACHED FACES-1. LATER (IN GEOM) EACH TIME A
C FACE IS FOUND ATTACHED TO THE EDGE, NCONN(3,EDGE) WILL BE INCREMENTED.
C /GPLANE,FINDIF, AND LOOP/.
C FINALLY, IT READS THE INCIDENT FIELD PARAMETERS. THETA AND PHI
C THE DIRECTION OF PROPAGATION OF THE PLANE WAVE.
```

```
C-----------------------------------------------------------------------
      COMPLEX ETHETA,EPHI,HTHETA,HPHI,CWVLT(MXWVLT)
      CHARACTER*2 ITYPE
      CHARACTER*1 IG
      DIMENSION DATNOD(3,MXBDND),EXCITE(7,MXEXCI)
      INTEGER NCONN(3,MXEDGS),IGNDP(3),NODVLT(MXWVLT)
      REAL MU,IMP
      LOGICAL PRINTC,THEV
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/PAT/PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA
      COMMON/GPLANE/NGNDP,IGNDP
      COMMON/FINDIF/NNFLD,DX,DY,DZ
      COMMON/LOOP/PRINTC,THEV,IETHEV MLTTHV
      COMMON/IGUANA/IG
C SET CONSTANT PARAMETERS FOR /MEDIUM/
      PI=3.14159265358979
      SL=2.997925E8
      MU=PI*4.0E-07
      EPSLON=1.0/(SL*SL*MU)
      IMP=SQRT(MU/EPSLON)
      DEG2RAD=PI/180.
C
C NJCT=0 FOR NO JUNCTION CASE, NJCT=1 OTHERWISE.
C MNJUN: NUMBER OF JUNCTIONS
      READ(2,*)NJCT,MNJUN
      WRITE(3,*)' NUMBER OF JUNCTION = ',MNJUN
C
      IF(NJCT.LE.0) MNJUN=1
      READ(2,*)NNODES,NEDGES
C
C CHECK IF DECLARED DIMENSION IS ENOUGH
C
      IF(NEDGES.GT.MXEDGS) THEN
      WRITE(6,*)'DECLARED DIMENSION FOR BODY IS INSUFFICIENT'
      STOP
      ENDIF
C
C FILL DATNOD WITH NODE LOCATIONS
C
      DO 10 I=1,NNODES
      READ(2,*) NODE,X,Y,Z
      DATNOD(1,NODE)=X
      DATNOD(2,NODE)=Y
      DATNOD(3,NODE)=Z
 10   CONTINUE
```

```
C
C FILL NCONN WITH EDGE CONNECTIONS.
C
      DO 20 I=1,NEDGES
      READ(2,* ) NE,NF,NT
      NCONN(1,NE)=NF
      NCONN(2,NE)=NT
      NCONN(3,NE)=-1
 20   CONTINUE
C
C TRANSFER INPUT DATA TO IGUANA FORMAT
C
       IF(IG.EQ.'Y')THEN
       WRITE(18,117)
117    FORMAT(' CM, INPUT DATA IN IGUANA FORMAT')
       WRITE(18,116)
116    FORMAT(' CE,')
       DO 119 NN=1,NEDGES
       N1=NCONN(1,NN)
       N2=NCONN(2,NN)
119    WRITE(18,128)NN,DATNOD(1,N1),DATNOD(2,N1),DATNOD(3,N1)
     $  ,DATNOD(1,N2),DATNOD(2,N2),DATNOD(3,N2)
128    FORMAT(' GW,',I3,',1,',F9.3,',',F9.3,',',F9.3,',',F9.3,',',F9.3,
     $',',F9.3,',0.1')
118    FORMAT(' GW',I3,4X,'1',6F10.4,5X,'0')
C
       ENDIF
C
C READ GROUND PLANE PARAMETERS. NGNDP=THE NUMBER OF GROUND PLANES.
C ,OR A P.M.C. GROUND PLANE RESPECTIVELY. I=1,2,3, DENOTES GROUND PLANES
C IN THE X=0,Y=0,AND Z=0 PLANES RESPECTIVELY.
C READ IN THE NUMBER OF NODES, EDGES, AND FIELD OBSERVETION POINTS.
      PRINTC=.TRUE.
      NNFLD=0
      READ(2,*)NGNDP
      READ(2,*)IGNDP(1),IGNDP(2),IGNDP(3)
      WRITE(3,1)NGNDP
  1   FORMAT(1X,'NUMBER OF IMAGE PLANES=',I3)
      WRITE(3,2)IGNDP(1),IGNDP(2),IGNDP(3)
  2   FORMAT(1X,'IMAGE PLANE NOTATION:',
     $/7X,' 0=NO GROUND PLANE',
     $/7X,' 1=A P.M.C. GROUND PLANE',
     $/7X,'-1=A P.E.C. GROUND PLANE',
     $/1X,I3,' IN THE X=0 PLANE',
     $/1X,I3,' IN THE Y=0 PLANE',
```

```
    $/1X,I3,' IN THE Z=0 PLANE')
C
C WRITE INFORMATION TO TAPE3
C
      WRITE(3,19)
 19   FORMAT(/20X,'VERTEX  COORDINATE  LIST')
      WRITE(3,21)
 21   FORMAT(18X,'ALL DIMENSIONS ARE IN METERS')
      WRITE(3,22)
 22   FORMAT(//1X,'VERTEX NUMBER',3X,'X-COORDINATE',2X,
     $'Y-COORDINATE  Z-COORDINATE')
      DO 30 I=1,NNODES
      WRITE(3,23)I,DATNOD(1,I),DATNOD(2,I),DATNOD(3,I)
 30   CONTINUE
 23   FORMAT(3X,I4,10X,1E12.5,2X,1E12.5,2X,1E12.5)
C     IF FAR FIELD PATTERN OR RADAR CROSS SECTION IS DESIRED.
C     IPAT=1 IF A 3 POINT QUADRATURE IS USED
C     IPAT=2 IF A 1 POINT QUADRATURE IS USED
C     OTHERWISE IPAT=0.
      READ(2,*)IPAT
      WRITE(3,*)' IPAT = ',IPAT
      WRITE(3,*)' IF IPAT.GT.0 FAR FIELD PATTERNS ARE COMPUTED'
      IF(IPAT.GT.0)THEN
C FAR FIELD PATTERN PARAMETERS IN SPHERICAL COORDINATES:
C PHI VARIES FROM PHI1 TO PHI2 (DEGREES) WITH NPHI(>0)POINTS.
C THETA VARIES FROM THETA1 TO THETA2 (DEGREES) WITH NTHETA(>0) POINTS.
        READ(2,*)PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA
        WRITE(3,*)' PATTERN PARAMETERS:'
        WRITE(3,*)' PHI1,     PHI2,     NPHI,     THETA1,
     &    THETA2,     NTHETA
        WRITE(3,8999)PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA
8999    FORMAT(1X,2(2F10.4,I5))
      ENDIF
      READ(2,*)ITOT
C       READ(2,*)NEXCIT
        NEXCIT=1
C READ THE INCIDENT FIELDS AND OR VOLTAGE SOURCES FOR WHICH THE CURRENT
C DISTRIBUTIONS NEED TO BE COMPUTED.
        DO 40 I40=1,NEXCIT
         READ(2,216) ITYPE
216     FORMAT(A2)
        IF(ITYPE.EQ.' P') THEN
        EXCITE(1,I40)=0.
C EXCITE(2-7,I40)=THETA, PHI, REALHTHETA, IMAGHTHETA, REALHPHI, IMAGHPHI
           READ(2,*)(EXCITE(I,I40),I=2,7)
```

```
           HTHETA=CMPLX(EXCITE(4,I40),EXCITE(5,I40))
           HPHI=CMPLX(EXCITE(6,I40),EXCITE(7,I40))
           ETHETA=-IMP*HPHI
           EPHI=IMP*HTHETA
C           WRITE(3,217)EXCITE(2,I40),EXCITE(3,I40)
C   217     FORMAT(/5X,'ANGLE OF INCIDENCE',/,10X,'THETA=',E12.5,1X,
C     $'DEGREES',/10X,'PHI=',E12.5,1X,'DEGREES')
C           WRITE(3,218) ETHETA,EPHI,HTHETA,HPHI
  218      FORMAT(/5X,'POLARIZATION',/,10X,'E-THETA= (',2E12.5,
     $') VOLTS/METER',
     $/,10X,'E-PHI=   (',2E12.5,') VOLTS/METER',
     $/,10X,'H-THETA= (',2E12.5,') AMPS/METER',
     $/,10X,'H-PHI=   (',2E12.5,') AMPS/METER')
        NWVLT=1
        CWVLT(1)=(0.,0.)
        ELSE
           EXCITE(1,I40)=1.
           DO II=2,7
           EXCITE(I,I40)=0.
           ENDDO
C READIN THE VOLTAGE STUFF
      READ(2,*)NWVLT

      WRITE(3,*)' NUMBER OF VOLTAGE SOURCE = ',NWVLTJ
      DO 39 N=1,NWVLT
      READ(2,*)NOD,RV,XV
      NODVLT(N)=NOD
      CWVLT(N)=CMPLX(RV,XV)
39    WRITE(3,*)' V = ',CWVLT(N),' VOLTS ON WIRE NODE ',NOD
      ENDIF
 40   CONTINUE
      RETURN
      END
```

A.24 WIRIN

```
C=====================================================================
      SUBROUTINE WIRIN(MXWNOD,MXWMLT,MXWSEG,NWNOD,NWSEG,NWUNKS,WNODE,
     $MULTW,NSEGC,WSEGH,RAD,INSEG,DATNOD,NNODES,NJCT,MNJUN,NWJUN,NBJUN)
C---------------------------------------------------------------------
C THIS SUBROUTINE READS
C TWO SETS OF INPUT DATA DEFINING THE WIRE OR WIRES.
* PARAMETERS PASSED INTO WIRGOM:
```

```
*  MXWNOD = MAXIMUM NUMBER OF WIRE NODES.
*  MXWMLT = MAXIMUM MULTIPLICITY THAT ANY WIRE NODE MAY HAVE.
*  MXWSEG = MAXIMUM NUMBER OF WIRE SEGMENTS.
*  MXWZN  = MAXIMUM NUMBER OF LUMPED IMPEDENCES ON WIRES.
* PARAMETERS PASSED FROM WIRGOM:
*  NWNOD  = NUMBER OF WIRE NODES.
*  NWSEG  = NUMBER OF WIRE SEGMENTS.
*  NWUNKS = NUMBER OF WIRE UNKNOWNS.
*  WNODE(I,J)I=1,2,3 CONTAINS THE X,Y,Z COORDINATES OF THE JTH WIRE NODE
*  MULTW(N) CONTAINS THE MULTIPLICITY OF THE NTH NODE.
*  NSEGC(I,J):THE JTH WIRE SEGMENT RUNS FROM NSEGC(1,J) TO NSEGC(2,J).
*  WSEGH(I,J) I=1,2,3 CONTAINS THE X,Y,Z COORDINATES OF THE MIDPOINT OF
*  JTH WIRE SEGMENT.
*  RAD(N) CONTAINS THE RADIUS OF THE NTH WIRE SEGMENT.
*  INSEG(M,N) M=1,...,MULTW(N)+1 ARE THE SEGMENTS (IN INCREASING ORDER)
*  ATTATCHED TO THE NTH WIRE NODE.
*  NWCZN = THE NUMBER OF LUMPED IMPEDENCE LOADS ON THE WIRE.
*  IWCZN(1,I) CONTAINS THE NODE LOCATION OF THE ITH IMPEDENCE LOAD,
*  IWCZN(2,I)=1 IF THE LOAD IS ON THE FIRST NODE OF THE SEGMENT
*            2 IF THE LOAD IS ON THE SECOND NODE OF THE SEGMENT
*  I=1,...,NWCZN.
*  CWZN(I) CONTAINS THE VALUE OF THE COMPLEX LUMPED IMPEDENCE FOR THE
*  IWCZN(1,I)TH NODE, I=1,...,NWCZN.
C-----------------------------------------------------------------------
      DIMENSION WNODE(3,MXWNOD),WSEGH(3,MXWSEG),RAD(MXWSEG),
     >    MULTW(MXWNOD),NSEGC(2,MXWSEG),INSEG(MXWMLT+1,MXWNOD),
     >    DATNOD(3,NNODES),NWJUN(MNJUN),NBJUN(MNJUN)
      CHARACTER*1 IG
      COMMON/IGUANA/IG
C
      READ(8,*)NWNOD,NWSEG
      WRITE(9,*)'      NODES      SEGMENTS
      WRITE(9,*)NWNOD,NWSEG
      WRITE(9,*)' '
C
C CHECK IF DECLARED DIMENSION IS ENOUGH
C
       IF(NWNOD.GT.MXWNOD.OR.NWSEG.GT.MXWSEG) THEN
       WRITE(6,*)'DECLARED DIMENSION FOR WIRE IS INSUFFICIENT'
       STOP
       ENDIF
C
* READ WIRE NODE DATA COORDINATES
C
       PI=3.1415926
```

```
      AK=2.*PI
      WRITE(9,*)'     NODE #     X               Y             Z
      DO 10 N=1,NWNOD
      READ(8,*)NN,WNODE(1,NN),WNODE(2,NN),WNODE(3,NN)
      WRITE(9,*)NN,WNODE(1,NN),WNODE(2,NN),WNODE(3,NN)
 10   CONTINUE
      WRITE(9,*)       SEG #       FROM         TO      RADIUS
      DO 20 N=1,NWSEG
      READ(8,*) NN,NSEGC(1,NN),NSEGC(2,NN),RAD(NN)
      WRITE(9,*) NN,NSEGC(1,NN),NSEGC(2,NN),RAD(NN)
 20   CONTINUE
C
C TRANSFER INPUT DATA TO NEC FORMAT
C
       IF(IG.EQ.'Y')THEN
       WRITE(12,117)
117    FORMAT('CM INPUT DATA IN NEC FORMAT')
       WRITE(12,116)
116    FORMAT('CE')
       WRITE(12,118)ITG,NWSEG,WNODE(1,1),WNODE(2,1),WNODE(3,1)
     $  ,WNODE(1,NWNOD),WNODE(2,NWNOD),WNODE(3,NWNOD),RAD(1)
C
C TRANSFER INPUT DATA TO IGUANA FORMAT
C
       WRITE(18,128)NWSEG,WNODE(1,1),WNODE(2,1),WNODE(3,1)
     $  ,WNODE(1,NWNOD),WNODE(2,NWNOD),WNODE(3,NWNOD),RAD(1)
118    FORMAT('GW',I3,I5,7F10.4)
128    FORMAT(' GW,999,',I3,',',F8.2,',',F8.2,',',F8.2,',',F8.2,',',F8.2,
     $',',F8.2,',',F8.4)
       WRITE(18,126)
126    FORMAT(' GE,')
       WRITE(18,127)
127    FORMAT(' EN,')
C
       ENDIF
C
* COMPUTE WIRE HALF NODES
C
      WRITE(9,*)'      SEG #       CENTER POINT COORDINATES'
      DO 30 N=1,NWSEG
        NFROM=NSEGC(1,N)
        NTO=NSEGC(2,N)
        DO 25 J=1,3
        WSEGH(J,N)=(WNODE(J,NFROM)+WNODE(J,NTO))*.5
 25     CONTINUE
```

```
      WRITE(9,*)N,WSEGH(1,N),WSEGH(2,N),WSEGH(3,N)
 30   CONTINUE
C
C MNJUN: NUMBER OF JUNCTION
C NWJUN(I):WIRE NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C NBJUN(I):BODY NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C
      IF(NJCT.EQ.1)THEN
      CALL FNDJUN(WNODE,NWNOD,DATNOD,NNODES,MNJUN,NWJUN,NBJUN)
      ELSE
      MNJUN=1
      NWJUN(1)=0
      NBJUN(1)=0
      ENDIF
C
      CALL WIRMUL(NJCT,MXWMLT,NWNOD,NWSEG,NSEGC,NWUNKS,MULTW,
     &INSEG,MNJUN,NWJUN)
      RETURN
      END
```

A.25 FACMUL

```
C==================================================================
       SUBROUTINE FACMUL(NCONN,NEDGES,ITRAK,
     $                   NBOUND,MXFACE,NFACES,NUNKNB)
C------------------------------------------------------------------
C THIS SUBROUTINE FILLS NBOUND WITH THE FACES FORMED BY THE EDGES
C IN NCONN. IT ALSO FILLS IN THE MULTIPLICITY FACTOR OF THE EDGE
C IN NCONN(3,EDGE). IT RETURNS THE NUMBER OF FACES(NFACES),
C AND THE NUMBER OF BODY UNKNOWNS(NUNKNB) WHICH IS EQUAL TO THE
C SUMMATION OF THE MULTIPLICITY FACTORS OF THE EDGES BEFORE GROUND
C PLANES ARE CONSIDERED. ITRAK IS A WORK ARRAY.
C------------------------------------------------------------------
      INTEGER NCONN(3,NEDGES),NBOUND(3,MXFACE),ITRAK(NEDGES)
       NFACES=0
       DO 100 IEDGE=1,NEDGES-2
         NTRAK=0
         DO 200 JEDGE=IEDGE+1,NEDGES
           DO 20 I=1,2
             DO 21 J=1,2
               IF(NCONN(I,IEDGE).EQ.NCONN(J,JEDGE))THEN
                 NTRAK=NTRAK+1
                 ITRAK(NTRAK)=JEDGE
```

```
              GOTO 200
            ENDIF
21        CONTINUE
20      CONTINUE
200   CONTINUE
      DO 300 JEDGE=1,NTRAK-1
        DO 301 KEDGE=JEDGE+1,NTRAK
          DO 30 J=1,2
            DO 31 K=1,2
          IF((NCONN(J,ITRAK(JEDGE)).EQ.NCONN(K,ITRAK(KEDGE))).AND.
     $    (NCONN(J,ITRAK(JEDGE)).NE.NCONN(1,IEDGE).AND.NCONN(J,ITRAK
     $    (JEDGE)).NE.NCONN(2,IEDGE)))THEN
                NFACES=NFACES+1
                NBOUND(1,NFACES)=IEDGE
                NBOUND(2,NFACES)=ITRAK(JEDGE)
                NBOUND(3,NFACES)=ITRAK(KEDGE)
                NCONN(3,IEDGE)=NCONN(3,IEDGE)+1
                NCONN(3,ITRAK(JEDGE))=NCONN(3,ITRAK(JEDGE))+1
                NCONN(3,ITRAK(KEDGE))=NCONN(3,ITRAK(KEDGE))+1
                GOTO 300
              ENDIF
31          CONTINUE
30        CONTINUE
301     CONTINUE
300   CONTINUE
100 CONTINUE
    NUNKNB=3*NFACES-NEDGES
    RETURN
    END
```

A.26 ORTFAC

```
C=========================================================================
      SUBROUTINE ORTFAC(NCONN,NBOUND,NFACES,NEDGES,MXDJBD,ITREE,ISTART,
     $                  NBODYS,NBE)
C-------------------------------------------------------------------------
C  ORIENT FACE NUMBER
C  ALL EDGES IN THE FIRST DISJOINT SURFACE ARE NUMBERED
C  CONSECUTIVELY STARTING FROM 1. THE EDGES IN THE NEXT DISJOINT
C  SURFACE ARE NUMBERED CONSECUTIVELY, STARTING WHERE THE LAST SURFACE
C  LEFT OFF.
C
C INPUT
```

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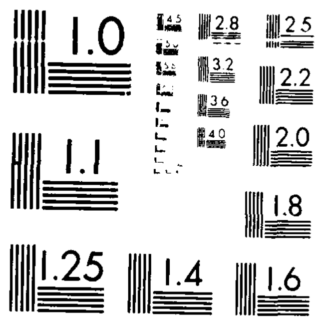

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
C
C  NCONN(3,NEDGES): EDGE J RUNS FROM VERTEX NCONN(1,J)
C  TO VERTEX NCONN(2,J)  NCONN(3,J)=MULTIPLICITY FACTOR OF THE EDGE
C  NBOUND(3,NFACES):EACH FACE J HAS ORDERED EDGES NBOUND(I,J) I=1,2,3
C                    J=1,2,...,NFACES.
C  NFACES EQUALS THE TOTAL NUMBER OF FACES.
C  NEDGES EQUALS THE TOTAL NUMBER OF EDGES.
C  MXDJBD EQUALS THE MAXIMUN NUMBER OF EXPECTED BODYS.
C
C OUTPUT:
C
C  ISTART(MXDJBD+1):ISTART(I)=THE LOWEST NUMBERED FACE ON THE ITH
C                             TREE(DISJOINT SURFACE)
C  ISTART(NBODYS+1)=NFACES+1
C  MXDJBD.GE.NBODYS OR ROUTINE STOPS AND PRINTS A WARNING.
C     ITREE(NFACES)
C     ITREE(I) I=1,...,ISTART(2)-1 =THE FACES ON THE FIRST TREE.
C     ITREE(I) I=ISTART(J),...,ISTART(J+1)-1,=THE FACES ON THE JTH TREE.
C  NBODYS EQUALS THE NUMBER OF DISJOINT SURFACES.
C  NBE(MXDJBD):NBE(I) CONTAINS THE NUMBER OF BOUNDRY EDGES FOR BODY I.
C
C  FOR EACH FACE,
C  IFACE=1,...,NFACES, THE EDGES IN NBOUND(IFACE,II),II=1,2,3
C  ARE REARRANGED SO THAT THEIR ORIENTATION IS CONSISTENT WITH
C  THE LOWEST NUMBERED FACE IN THE TREE CONTAINING IFACE.
C  TWO FACES WITH A COMMON EDGE ARE ORIENTED CONSISTENTLY WHEN THE
C  EDGE CROSS THE NORMAL TO THAT FACE POINTS OUT OF THAT FACE ACROSS THE
C  COMMON EDGE WHILE THE COMMON EDGE CROSS THE NORMAL OF THE CONTIGUOUS
C  FACE POINTS INTO THE CONTIGUOUS FACE ACROSS THE COMMON EDGE.
C  FOR CONVENIENCE ONE MAY CYCLICALLY PERMUTE EDGES 1,2,3 TO 2,3,1 OR
C  3,1,2 WITHOUT CHANGING THE FACE ORIENTATION.
C-----------------------------------------------------------------------
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),ITREE(NFACES),
     $            ISTART(MXDJBD+1),NBE(MXDJBD)
      NFACE1=NFACES+1
      NTREE=1
      LNF=1
      ITREE(LNF)=LNF
      ISTART(1)=LNF
      DO 1 NBODYS=1,MXDJBD
        DO 40 I40=1,3
          IF(NCONN(3,NBOUND(I40,LNF)).EQ.0)NBE(NBODYS)=NBE(NBODYS)+1
 40     CONTINUE
 51     DO 50 IFACE=LNF+1,NFACES
          DO 10 JTREE=LNF,NTREE
```

```
           IF(IFACE.EQ.ITREE(JTREE))GOTO 50
10       CONTINUE
         LOWFACE=NFACE1
         DO 20 JTREE=LNF,NTREE
           DO 30 I=1,3
             DO 31 J=1,3
               IF(NBOUND(I,IFACE).EQ.NBOUND(J,ITREE(JTREE)).AND.
     $            ITREE(JTREE).LT.LOWFACE)LOWFACE=ITREE(JTREE)
31           CONTINUE
30         CONTINUE
20       CONTINUE
         IF(LOWFACE.NE.NFACE1)THEN
           DO 60 I=1,3
             DO 61 J=1,3
               IF(NBOUND(I,IFACE).EQ.NBOUND(J,LOWFACE))THEN
                 NTREE=NTREE+1
                 ITREE(NTREE)=IFACE
                 DO 41 I41=1,3
                   IF(NCONN(3,NBOUND(I41,IFACE)).EQ.0)
     $             NBE(NBODYS)=NBE(NBODYS)+1
41               CONTINUE
                 ISLOT=I+1
                 JSLOT=J+1
                 IF(ISLOT.EQ.4)ISLOT=1
                 IF(JSLOT.EQ.4)JSLOT=1
               IF(NCONN(1,NBOUND(ISLOT,IFACE)).EQ.NCONN(1,NBOUND(JSLOT,
     $LOWFACE)).OR.NCONN(1,NBOUND(ISLOT,IFACE)).EQ.NCONN(2,NBOUND(JSLOT,
     $LOWFACE)).OR.NCONN(2,NBOUND(ISLOT,IFACE)).EQ.NCONN(1,NBOUND(JSLOT,
     $LOWFACE)).OR.NCONN(2,NBOUND(ISLOT,IFACE)).EQ.NCONN(2,NBOUND(JSLOT,
     $LOWFACE)))THEN
                   IDUM=NBOUND(1,IFACE)
                   NBOUND(1,IFACE)=NBOUND(2,IFACE)
                   NBOUND(2,IFACE)=IDUM
                 ENDIF
                 GOTO 51
               ENDIF
61           CONTINUE
60         CONTINUE
         ENDIF
50     CONTINUE
       LNF=NTREE+1
       IF(LNF.LE.NFACES)THEN
         ISTART(NBODYS+1)=LNF
         NTREE=NTREE+1
         ITREE(NTREE)=LNF
```

```
        ELSE
          GOTO 999
        ENDIF
1     CONTINUE
      WRITE(1,99)
99    FORMAT(1X,'WARNING IN CURDIR MXDJBD FOUND BUT STILL HAVE FACES
     $LEFT')
      STOP
999   CONTINUE
      ISTART(NBODYS+1)=NFACES+1
      RETURN
      END
```

A.27 CLSBOD

```
C=================================================================
      SUBROUTINE CLSBOD(DATNOD,NCONN,NBOUND,NNODES,NEDGES,NFACES,I,
     $                  ISTART)
C-----------------------------------------------------------------
C THIS SUBROUTINE IS CALLED ONLY IF THE BODY IS CLOSED. IN THIS
C CASE, THIS SUBROUTINE ORIENTS THE NORMAL POINTING INTO THE
C SURROUNDING MEDIUM. THE VOLUME OF THE BODY IS ALSO CALCULATED.
C THE VOLUME IS COMPUTED BY USE OF THE IDENTITY:
C  VOLUME = THE INTEGRAL OVER THE SURFACE BOUNDING THE VOLUME OF THE X
C          COMPONENT OF THE SURFACE NORMAL TIMES X TIMES THE
C          DIFFERENTIAL SURFACE AREA.
C------------------------------------------------------------------
      DIMENSION DATNOD(3,NNODES),J(3),NJ(3),DJ(3,3)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),ISTART(NFACES+1)
      COMMON/VOL/VOLUME
      VOLUME=0.0
      DO 15 IJ= ISTART(I),ISTART(I+1)-1
        CALL FACEDG(NFACES,NBOUND,IJ,J)
        CALL FACVTX(NCONN,NEDGES,J,NJ)
        X=(DATNOD(1,NJ(1))+DATNOD(1,NJ(2))+DATNOD(1,NJ(3)))/3.0
        CALL VTXCRD(DATNOD,NNODES,NJ,DJ)
      ARJ1=(DJ(2,2)-DJ(1,2))*(DJ(3,3)-DJ(1,3))-(DJ(3,2)-DJ(1,2))*
     $      (DJ(2,3)-DJ(1,3))
        VOLUME=VOLUME+X*ARJ1/2.0
15    CONTINUE
      IF(VOLUME LT.0.0) THEN
        DO 16 I16= ISTART(I),ISTART(I+1)-1
          IDUMMY=NBOUND(1,I16)
```

```
          NBOUND(1,I16)=NBOUND(2,I16)
          NBOUND(2,I16)=IDUMMY
16      CONTINUE
        ENDIF
        RETURN
        END
```

A.28 FACOUT

```
C=====================================================================
      SUBROUTINE FACOUT(NCONN,NBOUND,ISTART,I,NEDGES,NFACES,
     $                  NBODYS,DATNOD,NNODES)
C---------------------------------------------------------------------
C THIS SUBROUTINE PRINTS THE EDGES AND THE VERTICES OF EACH FACE.
C INPUT:
C  NCONN HAS THE VERTICIES AND THE MULTIPLICITY FACTOR FOR EACH EDGE.
C  NBOUND HAS THE EDGES FOR EACH FACE.
C  ISTART HAS THE BEGINNING FACES FOR EACH BODY.
C  I IS THE PRESENT BODY.
C  NEDGES IS THE TOTAL NUMBER OF EDGES.
C  NFACES IS THE TOTAL NUMBER OF FACES.
C  NBODYS IS THE TOTAL NUMBER OF BODYS.
C---------------------------------------------------------------------
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),ISTART(NBODYS+1),NV(3)
     $           ,NB(3)
      REAL DATNOD(3,NNODES),DN(3,3)
      CHARACTER*1 IG
      COMMON/IGUANA/IG
      WRITE(3,102)I
 102  FORMAT(//20X,'FOR BODY NUMBER:',I3/)
      DO 10 I10=ISTART(I),ISTART(I+1)-1
C OBTAIN THE EDGES OF THE TRIANGLE
      DO 2 I=1,3
2      NB(I)=NBOUND(I,I10)
C OBTAIN THE VERTICES OF THE TRIANGLE
       CALL FACVTX(NCONN,NEDGES,NB,NV)
        WRITE(3,98)I10,NBOUND(1,I10),NBOUND(2,I10),NBOUND(3,I10),
     $  NV(1),NV(2),NV(3)
C
C TRANSFER INPUT DATA TO NEC FORMAT
C
        IF(IG.EQ.'Y')THEN
C OBTAIN THE COORDINATES OF THE TRIANGLE'S VERTICIES
```

```
        CALL VTXCRD(DATNOD,NNODES,NV,DN)
58      WRITE(12,112)DN(1,1),DN(1,2),DN(1,3),DN(2,1),
     $  DN(2,2),DN(2,3)
        WRITE(12,113)DN(3,1),DN(3,2),DN(3,3)
        ENDIF
112     FORMAT('SP',7X,'2',6F10.4)
113     FORMAT('SC',7X,'2',3F10.4)
C
 10   CONTINUE
 98   FORMAT(1X,'FACE',I4,'  HAS EDGES',3I4,'  WITH VERTICES',3I4)
C TRANSFER INPUT DATA TO NEC FORMAT
C
        IF(IG.EQ.'Y')THEN
        WRITE(12,116)
116     FORMAT('GE')
        WRITE(12,117)
117     FORMAT('EN')
        ENDIF
      RETURN
      END
```

A.29 ADBMUL

```
C=============================================================
      SUBROUTINE ADBMUL(NNODES,NEDGES,DATNOD,NCONN,NUNKNB)
C-------------------------------------------------------------
C ADJUST MULTIPLICITY OF BODY EDGE
C INPUT:
C  NNODES=THE NUMBER OF BODY NODES.
C  NEDGES=THE NUMBER OF EDGES.
C  NUNKNB=THE NUMBER OF BODY UNKNOWNS BEFORE CONSIDERING THE
C     GROUND PLANE ATTACHMENTS.
C  DATNOD(I,N)=THE X,Y,Z COMPONENTS(I=1,2,3) OF THE NTH NODE N=1,NNODES.
C  NCONN(I,IE) I=1,2,3: EDGE IE (IE=1,NEDGES) RUNS FROM NODE NCONN(1,IE)
C     TO NCONN(2,IE) AND HAS MULTIPLICITY NCONN(3,IE)(BEFORE ANY GROUND
C     PLANE ATTACHMENTS ARE CONSIDERED).
C
C OUTPUT:
C  FOR EACH EDGE IE THAT IS CONNECTED TO A P.E.C. GROUND PLANE AND IS
C  NOT CONNECTED TO A P.M.C. GROUND PLANE, ITS MULTIPLICITY(NCONN(IE,3))
C  AND THE NUMBER OF BODY UNKNOWNS(NUNKNB) ARE INCRIMENTED BY 1.
C  THE EDGE VERTEX CONNECTION LIST WITH EDGE MULTIPLICITIES IS OUTPUTTED
C  AFTER ACCOUNTING FOR ALL GROUND PLANE ATTACHMENTS.
```

```
C-----------------------------------------------------------------------
      DIMENSION DATNOD(3,NNODES),NCONN(3,NEDGES),IGNDP(3),D1(3), '(3),
     $              DM(3)
      COMMON/GPLANE/NGNDP,IGNDP
      IF(NGNDP.GT.0)THEN
        EDGED=1.E-4
        DO 100 IE=1,NEDGES
          N1=NCONN(1,IE)
          N2=NCONN(2,IE)
      DO 2 I=1,3
      D1(I)=ABS(DATNOD(I,N1))
      D2(I)=ABS(DATNOD(I,N2))
2      DM(I)=AMAX1(D1(I),D2(I))
          IX=0
          IY=0
          IZ=0
          IF(DM(1).LE.EDGED)IX=IGNDP(1)
          IF(IX.NE.1)THEN
            IF(DM(2).LE.EDGED)IY=IGNDP(2)
            IF(IY.NE.1.AND.DM(3).LE.EDGED)IZ=IGNDP(3)
          ENDIF
          IMAX=AMAX0(IX,IY,IZ)
          IF(IMAX.NE.1)THEN
            IMIN=AMIN0(IX,IY,IZ)
            NUNKNB=NUNKNB-IMIN
            NCONN(3,IE)=NCONN(3,IE)-IMIN
          ENDIF
 100    CONTINUE
      ENDIF
      WRITE(3,29)
 29   FORMAT(//14X,'EDGE-VERTEX CONNECTION LIST'/)
      DO 40 I=1,NEDGES
        WRITE(3,331)I,NCONN(1,I),NCONN(2,I),NCONN(3,I)
 40   CONTINUE
 331  FORMAT(3X,'EDGE',I4,' GOES FROM VERTEX',I4,' TO VERTEX',I4,
     $' MULT=',I2)
      RETURN
      END
```

A.30 BODPAR

```
C=======================================================================
      SUBROUTINE BODPAR(DATNOD,NCONN,NBOUND,NNODES,NEDGES,NFACES,NUNKNB)
```

```
C-----------------------------------------------------------------------
C COMPUTE PARAMETERS ASSOCIATED WITH BODY
C INPUT:
C  DATNOD(I,J) I=1,2,3 ARE THE X,Y,Z COORDINATES OF THE JTH NODE.
C  NCONN(3,J): EDGE J RUNS FROM NODE NCONN(1,J) TO NODE NCONN(2,J)
C              NCONN(3,J) IS THE MULTIPLICITY OF THE JTH EDGE.
C  NBOUND(I,J): CONTAINS THE ITH EDGE OF THE JTH FACE I=1,2,3.
C  NNODES = THE NUMBER OF BODY NODES.
C  NEDGES = THE NUMBER OF EDGES.
C  NFACES = THE NUMBER OF FACES.
C  NUNKNB = THE NUMBER OF BODY UNKNOWNS.
C
C OUTPUT:
C  AVEDGE = THE AVERAGE EDGE LENGTH(METERS**2) INCLUDING MULTIPLICITY.
C  EDGEMX = THE MAXIMUN EDGE LENGTH(METERS).
C  MXEDGE = THE EDGE NUMBER OF THE EDGE WITH LENGTH EDGEMX.
C  EDGEMN = THE MINIMUM EDGE LENGTH(METERS).
C  MNEDGE = THE EDGE NUMBER OF THE EDGE WITH LENCTH EDGEMN.
C  TAREA = THE SURFACE AREA OF THE SCATTER(METERS**2):FOR THIN
C          STRUCTURES ONLY ONE SIDE IS CONSIDERED IN THE SURFACE AREA.
C  AVAREA = THE AVERAGE AREA OF THE FACES.
C  MXAREA = THE NUMBER OF THE FACE WITH THE MAXIMUN AREA(AREAMX).
C  MNAREA = THE NUMBER OF THE FACE WITH THE MINIMUM AREA(AREAMN).
C  RATIO = THE MINIMUM HEIGHT TO BASE RATIO OVER ALL FACES.
C  MNRTIO = THE FACE NUMBER THAT HAS A HEIGHT TO BASE RATIO OF "RATIO".
C-----------------------------------------------------------------------
      COMMON/PARAMS/AVEDGE,EDGEMX,MXEDGE,EDGEMN,MNEDGE,TAREA,AVAREA,
     $                 MXAREA,MNAREA,AREAMX,AREAMN,RATIO,MNRTIO
      COMMON/MCHVAL/VALMAX,VALMIN
      DIMENSION DATNOD(3,NNODES),DL(3,3),AL(3),RS(3),HTB(3),DV(3),DX(3),
     $           DN(3,3)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IS(3),NV(3)
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      SEDGL=0
      EDGEMX=VALMIN
      EDGEMN=VALMAX
      DO 20 IE=1,NEDGES
        MULT=NCONN(3,IE)
        N1=NCONN(1,IE)
        N2=NCONN(2,IE)
        DO 2 I=1,3
 2      DX(I)=DATNOD(I,N2)-DATNOD(I,N1)
        EDGL=SIZE(DX(1),DX(2),DX(3))
        SEDGL=SEDGL+MULT*EDGL
        IF(EDGL.GT.EDGEMX)THEN
```

```
        EDGEMX=EDGL
        MXEDGE=IE
      ENDIF
      IF(EDGL.LT.EDGEMN)THEN
        EDGEMN=EDGL
        MNEDGE=IE
      ENDIF
 20   CONTINUE
      AVEDGE=SEDGL/NUNKNB
      RATIO=VALMAX
      AREAMX=VALMIN
      AREAMN=VALMAX
      TAREA=0.
      DO 40 IFACE=1,NFACES
       DO 4 I=1,3
 4       IS(I)=NBOUND(I,IFACE)
        CALL FACVTX(NCONN,NEDGES,IS,NV)
        CALL VTXCRD(DATNOD,NNODES,NV,DN)
         DO 6 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      DO 6 J=1,3
6      DL(I,J)=DN(IM1,J)-DN(IP1,J)
      DO 8 J=1,3
      JP1=MOD(J,3)+1
      JM1=MOD(J+1,3)+1
8      DV(J)=DL(2,JP1)*DL(1,JM1)-DL(2,JM1)*DL(1,JP1)
        AREA2=SIZE(DV(1),DV(2),DV(3))
      AREA=.5*AREA2
      DO 3 I=1,3
      AL(I)=SIZE(DL(I,1),DL(I,2),DL(I,3))
      RS(I)=AL(I)*AL(I)
3       HTB(I)=AREA2/RS(I)
        HTBMIN=AMIN1(HTB(1),HTB(2),HTB(3))
        TAREA=TAREA+AREA
        IF(AREA.GT.AREAMX)THEN
          MXAREA=IFACE
          AREAMX=AREA
        ENDIF
        IF(AREA.LT.AREAMN)THEN
          MNAREA=IFACE
          AREAMN=AREA
        ENDIF
        IF(HTBMIN.LT.RATIO)THEN
          MNRTIO=IFACE
```

```
         RATIO=HTBMIN
        ENDIF
40     CONTINUE
       AVAREA=TAREA/NFACES
       WRITE(3,110)
110    FORMAT(//25X,'BODY PARAMETER LIST'/)
       WRITE(3,111) NNODES,NEDGES,NFACES,NUNKNB
111    FORMAT(10X,'NUMBER OF VERTICES= ,I4,
      $/10X,'NUMBER OF EDGES=',I4,
      $/10X,'NUMBER OF FACES=',I4,
      $/10X,'NUMBER OF EDGES INCLUDING MULTIPLICITY=',I4)
       WRITE(3,205)
205    FORMAT(//25X,'MODELING PARAMETER LIST (METERS)'/)
       WRITE(3,206) TAREA
206    FORMAT(10X,'SURFACE AREA OF THE SCATTERER=',E12.5,1X,'SQ.METERS')
       WRITE(3,209) AVEDGE,MXEDGE,EDGEMX,MNEDGE,EDGEMN
209    FORMAT(10X,'AVERAGE EDGE LENGTH=',1E12.5,1X,'METERS',
      $/10X,'MAXIMUM EDGE LENGTH(EDGE NO.',I3,1X,')=',E12.5,1X,'METERS',
      $/10X,'MINIMUM EDGE LENGTH(EDGE NO.',I3,1X,')=',E12.5,1X,'METERS')
       WRITE(3,210) AVAREA,MXAREA,AREAMX,MNAREA,AREAMN
210    FORMAT(10X,'AVERAGE FACE AREA =',E12.5,1X,'SQ.METERS',/10X,
      $'MAXIMUM FACE AREA (FACE NO.',I4,1X,')=',E12.5,1X,'SQ.METERS',/
      $10X,'MINIMUM FACE AREA (FACE NO.',I4,1X,')=',E12.5,1X,'SQ.METERS')
       WRITE(3,211) MNRTIO,RATIO
211    FORMAT(10X,'MINIMUM FACE HEIGHT TO BASE RATIO (FACE NO.',
      $I4,1X,')=',E11.5)
       RETURN
       END
```

A.31 EDGFAC

```
C=====================================================================
      SUBROUTINE EDGFAC(NCONN,NEDGES,NBOUND,NFACES,IEDGF,MULT1)
C---------------------------------------------------------------------
C MAPPING FROM EDGE TO FACE
C INPUT:
C  EDGE IE RUNS FROM VERTEX NCONN(1,IE) TO VERTEX NCONN(2,IE)
C  AND HAS MULTIPLICITY NCONN(3,IE).
C  FACE IFACE HAS EDGES NBOUND(J,IFACE) J=1 2,3
C  MULT1 IS SET IN THE MAIN PROGRAM AND MULT1-1.GE.THE
C  MAXIMUM MULTIPLICITY OF ANY EDGE.
C  OUTPUT:
C  ARRAY IEDGF
```

```
C  FOR AN EDGE WITH MULTIPLICITY MULT
C  IEDGF(2,IE)=THE NEXT LOWEST NUMBERED FACE CONNECTED TO IE.
C  ............
C  IEGDF(MM,IE)=THE LAST FACE CONNECTED TO IE.
C  WHERE MM IS THE NUMBER OF FACES CONNECTED TO EDGE IE.
C-----------------------------------------------------------------
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IEDGF(MULT1,NEDGES)
      DO 5 IE=1,NEDGES
        DO 6 M=1,MULT1
          IEDGF(M,IE)=0
 6      CONTINUE
 5    CONTINUE
      DO 100 IE=1,NEDGES
        MULTE1=NCONN(3,IE)+1
        M=0
        DO 50 IF=1,NFACES
          IF(M.GE.MULTE1)GO TO 100
          IF(IE.EQ.NBOUND(1,IF).OR.IE.EQ.NBOUND(2,IF).OR.IE.EQ.
     $ NBOUND(3,IF))THEN
            M=M+1
            IEDGF(M,IE)=IF
          ENDIF
 50     CONTINUE
 100  CONTINUE
      DO 200 IE=1,NEDGES
        WRITE(3,201)IE
        WRITE(3,*)(IEDGF(M,IE),M=1,NCONN(3,IE)+1)
 200  CONTINUE
 201  FORMAT(1X,'EDGE',I4,' IS ATTACHED TO FACES')
      RETURN
      END
```

A.32 SOLTN

```
C=================================================================
       SUBROUTINE SOLTN(CZ,CV,NUNKNT,IPVT,CWORK,DATNOD,NCONN,NBOUND,
     $ NEDGES,NFACES,NNODES,IEDGF,MULT1,EXCITE,NEXCIT,
     $     MXFREQ,INDSUM,NUNKNB,NWNOD,NWSEG,NWUNKS,WNODE,MULTW,NSEGC,
     &     WSEGH,RAD,INSEG,NJCT,MNJUN,NWJUN,NBJUN,
     &WIRSUM,ANG,MNJFACE,NJFACE,MIFACE,MXWMLT,NWWVLT,NODVLT,CWWVLT,
     &IPAT,ITOT)
C-----------------------------------------------------------------
C IN THIS SUBROUTINE, THE MATRIX EQUATION ZI=V IS SOLVED.
```

```
      IMPLICIT COMPLEX (C)
C
      REAL ANG(MNJUN,MNJFACE)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &  NWJUN(MNJUN)
C
      DIMENSION WNODE(3,NWNOD),WSEGH(3,NWSEG),RAD(NWSEG)
      INTEGER MULTW(NWNOD),NSEGC(2,NWSEG),WIRSUM(NWNOD),
     >        INSEG(MXWMLT+1,NWNOD)
      COMPLEX CZ(NUNKNT,NUNKNT),CV(NUNKNT),CWORK(NUNKNT)
      COMPLEX HTHETA,HPHI,ETHETA,EPHI
      REAL LAMBDA,K,MU,IMP
      DIMENSION DATNOD(3,NNODES),EXCITE(7,NEXCIT)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IEDGF(MULT1,NEDGES),
     $IPVT(NUNKNT),INDSUM(NEDGES)
C FOR WIRE
      INTEGER NODVLT(NWWVLT)
      COMPLEX CWWVLT(NWWVLT)
      LOGICAL PRINTC
      CHARACTER*1 IC
C
      COMMON/LOOP/PRINTC,THEV,IETHEV,MLTTHV
      COMMON/PARAM/THETA,PHI,IFIELD
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/FINDIF/NNFLD,DX,DY,DZ
      COMMON/F/FREQ
      COMMON/CPU/TGG,IC
      DO 20 IFREQ=1,MXFREQ
C READ IN THE FREQUENCY IN HERTZ.
        READ( 2,*) FREQ
        IF(FREQ.EQ.-1.)STOP
        WRITE(3,999)FREQ
        WRITE(4,999)FREQ
 999    FORMAT(1X,'FREQ=',1PE12.5)
C  LAMBDA=THE WAVELENGTH.
C  K=THE WAVE NUMBER.
C  OMEGA=THE ANGULAR FREQUENCY.
        OMEGA=2.*PI*FREQ
        K=OMEGA/SL
        LAMBDA=SL/FREQ
        IFIELD=0
        DO 11 J=1,NUNKNT
          DO 10 I=1,NUNKNT
```

```
          CZ(I,J)=(0.0,0.0)
 10      CONTINUE
 11     CONTINUE
        DO 40 I40=1,NEXCIT
          IFIELD=IFIELD+1
C INITIALIZE THE VOLTAGE VECTORS.
          DO 14  I=1,NUNKNT
            CV(I)=(0.0,0.0)
  14      CONTINUE
          IF(EXCITE(1,NEXCIT).EQ.0.) THEN
C IF EXCITATION IS A PLANE WAVE
C HTHETA AND HPHI REPRESENT THE AMPLITUDE OF THE INCIDENT PLANE WAVE.
          HTHETA=CMPLX(EXCITE(4,I40),EXCITE(5,I40))
          HPHI=CMPLX(EXCITE(6,I40),EXCITE(7,I40))
          ETHETA=-IMP*HPHI
          EPHI=IMP*HTHETA
          THETA=EXCITE(2,I40)*DEG2RAD
          PHI=EXCITE(3,I40)*DEG2RAD
          ELSE
C IF EXCITATION IS A VOLTAGE SOURCE
      IF(NJCT.GE.0) THEN
          CALL WCUMUL(NWNOD,NUNKNB,MULTW,WIRSUM)
          DO 144 IV=1,NWWVLT
          NODV=NODVLT(IV)
          NROW=WIRSUM(NODV)+1
144       CV(NROW)=CWWVLT(IV)
          ENDIF
      ENDIF
C
C INPUT:
C MNJUN: NUMBER OF JUNCTION
C NWJUN(I):WIRE NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C NBJUN(I):BODY NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C MNJFACE:MAXIMUN NUMBER OF FACE ATTACHED TO JUNCTION
C OUTPUT:
C NJFACE(I,J):FACE NUMBER OF THE JTH FACE ATTACHED TO THE ITH JUNCTION
C I=1,MNJUN, J=1,MIFACE(I)
C MIFACE(I):MAXIMUN NUMBER OF FACE ATTACHED TO THE ITH JUNCTION
C ANG(I,J):ANGLE FACTOR OF THE JTH PATCH ATTACHED TO THE ITH JUNCTION
C
      IF(NJCT.EQ.1)THEN
C
C COMPUTE PARAMETERS ASSOCIATE WITH JUNCTIONS
C
      CALL JUNFAC(NBJUN,MNJUN,NBOUND,NFACES,NCONN,NEDGES,
```

```
     &      NJFACE,MNJFACE,MIFACE)
      CALL JANGLE(DATNOD,NNODES,NBJUN,MNJUN,NBOUND,NFACES,NCONN,
     &      NEDGES,NJFACE,MNJFACE,MIFACE,ANG)
      ENDIF
C
      CALL BCUMUL(NCONN,INDSUM,NEDGES)
      IF(NJCT.GE.0) THEN
C
C FILL ZWW, ZBW, AND ZJW OF THE IMPEDANCE MATRIX
C
      CALL WIRMAN(IFREQ,CZ,CV,NUNKNT,NUNKNB,NWNOD,NWSEG,NWUNKS,
     & WNODE,MULTW,NSEGC,WSEGH,RAD,INSEG,WIRSUM,DATNOD,
     & NCONN,NBOUND,NNODES,NEDGES,NFACES,IEDGF,MULT1,INDSUM,NJCT,MNJUN,
     & NWJUN,NBJUN,NJFACE,MNJFACE,MIFACE,ANG,MXWMLT,IPAT)
      ENDIF
C
C FILL ZBB OF THE IMPEDANCE MATRIX
C
      CALL ZBB(DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,NEDGES,
     $     NFACES,NUNKNT,CZ,CV,INDSUM,NJCT,MNJUN,MNJFACE,NWNOD,WIRSUM,
     &     ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C
C FILL ZWB OF THE IMPEDANCE MATRIX
C
      IF(NJCT.GE.0) THEN
      CALL ZWB(DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,NEDGES,
     $      NFACES,NUNKNT,CZ,INDSUM,NWNOD,NWSEG,WNODE,NSEGC,WSEGH,
     $      MXWMLT,MULTW,INSEG,WIRSUM,NUNKNB,NJCT,MNJUN,MNJFACE,ANG,
     &      NJFACE,MIFACE,NWJUN,NBJUN)
      ENDIF
C
       WRITE(6,*)' '
       WRITE(6,*)'*** MATRIX FILLING COMPLETED ***'
C
       IF(IC.EQ.'Y')THEN
C
C CALL RUNTIME LIBRARY
C
       IERR=LIB$STAT_TIMER( 2, ITG1, )
       TG2=FLOAT(ITG1)/6000.
       TGF=TG2-TGG
C
        WRITE(6,*)'CPUTIME FOR MATRIX FILLING = ',TGF,' MINUTES'
        ENDIF
C
```

```
      WRITE(6,*)' '
      WRITE(6,*)' EXECUTION ........'
C
C CALL ROUTINES TO SOLVE MATRIX EQUATION
C CGEFA AND CGESL ARE SUBROUTINES IN LINPACK LIBRARY
C
         IF(IFIELD.EQ.1)CALL CGEFA(CZ,NUNKNT,NUNKNT,IPVT,INFO)
          IF(INFO.EQ.0) THEN
           CALL CGESL(CZ,NUNKNT,NUNKNT,IPVT,CV,0)
         ELSE
           WRITE(1,8)
 8         FORMAT(23H THE MATRIX IS SINGULAR)
           STOP
         ENDIF
 777  CONTINUE
      WRITE(6,*)' '
      WRITE(6,*)'*** MATRIX EQUATION SOLVED ***'
      WRITE(6,*)' '
C
      IF(IC.EQ.'Y')THEN
C
C CALL RUNTIME LIBRARY
C
      IERR=LIB$STAT_TIMER( 2, ITG2, )
      TG3=FLOAT(ITG2)/6000.
      TGS=TG3-TG2
C
       WRITE(6,*)'CPUTIME FOR MATRIX SOLVING = ',TGS,' MINUTES'
       WRITE(6,*)' '
       WRITE(6,*)'              TOTAL UNKNOWN NUMBER = ',NUNKNT
       WRITE(6,*)' '
       WRITE(6,*)'              TOTAL CPUTIME = ',TG3,' MINUTES'
       ENDIF
       WRITE(6,*)' '
       WRITE(6,*)'*** OUTPUT DATA FOR BODIES IN FOR003.DAT ***'
       IF(NJCT.GE.0)WRITE(6,*)'*** OUTPUT DATA FOR WIRES IN FOR009.DAT
     &***'
       WRITE(6,*)'*** CURRENTS ON SYSTEM IN FOR004.DAT ***'
C
         IF(PRINTC)THEN
C
C   WRITE THE CURRENT DENSITY TABLE.
C
           WRITE(3,22)
           WRITE(4,22)
```

```
 22         FORMAT(//28X,'SURFACE CURRENTS'/)
            WRITE(3,23)
            WRITE(4,23)
 23         FORMAT(1X,'EDGE NUMBER ',13X,'CURRENT DENSITY (AMPS/METER)')
            WRITE(3,24)
            WRITE(4,24)
 24         FORMAT(14X,'REAL',9X,'IMAGINARY',7X,'MAGNITUDE',7X,
     $'PHASE(DEG)')
            CO=(0.,0.)
            K1=0
            DO 50 I50=1,NEDGES
              IF(NCONN(3,I50).EQ.0)THEN
                WRITE(3,101)I50,CO,0.
                WRITE(4,101)I50,CO,0.
                A=0
                ELSE
                DO 35 I35=1,NCONN(3,I50)
                  K1=K1+1
                  RA1=REAL(CV(K1))
                  RA2=AIMAG(CV(K1))
                  RA3=CABS(CV(K1))
                  EPS=1.E-7
                  IF(ABS(RA1).LT.EPS)THEN
                  RA4=90.
                  ELSE
                  RA4=ATAN2(RA2,RA1)/DEG2RAD
                  ENDIF
                  WRITE(3,101) I50,RA1,RA2,RA3,RA4
                  WRITE(4,101) I50,RA1,RA2,RA3,RA4
  35            CONTINUE
              ENDIF
  50        CONTINUE
 101        FORMAT(2X,I4,2X,3(2X,E12.5,2X),F12.3)
          ENDIF
C
C PRINT CURRENTS ON THE WIRES
C
      CALL WIROUT(CV,NUNKNT,NUNKNB,MULTW,NWNOD)
C
 40     CONTINUE
C------------------------------------------------------------------
C COMPUTE FAR FIELD
C
      IF(IPAT.GT.0) THEN
C
```

```
      CALL PATTEN(DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,WIRSUM,
     $NEDGES,NFACES,NUNKNT,CV,INDSUM,IPAT,NJCT,MNJUN,MNJFACE,NWNOD,
     $ANG,NJFACE,MIFACE,NWJUN,NBJUN,MXWMLT,NWSEG,NUNKNB,WNODE,MULTW,
     $NSEGC,WSEGH,RAD,INSEG)
C
        WRITE(6,*)'*** PATTERN OUTPUT IN FOR010.DAT ***'
C
      ENDIF
C-----------------------------------------------------------------
C COMPUTE CHARGE DENSITY
C
      IF(ITOT.GT.0)THEN
C
      CALL CHARGE(NJCT,CV,DATNOD,NCONN,NBOUND,NNODES,NEDGES,
     $NFACES,NUNKNT,NWNOD,NWSEG,NUNKNB,WNODE,WIRSUM,NSEGC,MULTW,
     $ MNJUN,MNJFACE,ANG,NJFACE,MIFACE,NWJUN,NBJUN,INDSUM,
     $IEDGF,MULT1,INSEG,MXWMLT)
C
        WRITE(6,*)'*** CHARGE DENSITY OUTPUT IN FOR011.DAT ***'
        ENDIF
C-----------------------------------------------------------------
 20   CONTINUE
       RETURN
      END
```

A.33 WIRMUL

```
C================================================================
      SUBROUTINE WIRMUL(NJCT,MXWMLT,NWNOD,NWSEG,NSEGC,NWUNKS,MULTW,
     &           INSEG,MNJUN,NWJUN)
C----------------------------------------------------------------
C FIND MULTIPLICITY FOR EACH NODE
* INPUT:
*  MXWMLT=MAXIMUM MULTIPLICITY OF ANY WIRE NODE.
*  NWNOD=NUMBER OF WIRE NODES.
*  NWSEG=NUMBER OF WIRE SEGMENTS.
*  NSEGC(J,N) J+1,2 N=1,NWNOD
*  THE NTH WIRE SEGMENT RUNS FROM NODE NSEGC(1,N) TO NSEGC(2,N).
* OUTPUT:
*  NWUNKS=THE NUMBER OF WIRE UNKNOWNS.
*  MULTW(N)=THE MULTIPLICITY OF THE NTH WIRE NODE,N=1,...,NWNOD.
*  INSEG(M,N) M=1,...,MULTW(N)+1 ARE THE NUMBERS OF THE SEGMENTS
*  (IN INCREASING ORDER)THAT ARE ATTACHED TO THE NTH NODE.
```

```
C-----------------------------------------------------------------
      DIMENSION MULTW(NWNOD),NSEGC(2,NWSEG),INSEG(MXWMLT+1,NWNOD)
     &          ,NWJUN(MNJUN)
C
      NWUNKS=0
      DO 1 N=1,NWNOD
      MULTW(N)=-1
  1   CONTINUE
      DO 6 N=1,NWNOD
        DO 5 J=1,MXWMLT+1
          INSEG(J,N)=0
  5     CONTINUE
  6   CONTINUE
      DO 100 N=1,NWNOD
      MULTW(N)=-1
C
C ADD 1 TO MULTW(N) IF N IS A JUNCTION NODE
C
      IF(NJCT.EQ.1) THEN
      DO 11 NJ=1,MNJUN
11    IF(N.EQ.NWJUN(NJ))MULTW(N)=0
      ENDIF
C
        DO 50 NS=1,NWSEG
          IF(NSEGC(1,NS).EQ.N.OR.NSEGC(2,NS).EQ.N)THEN
            MULTW(N)=MULTW(N)+1
            M=MULTW(N)+1
            INSEG(M,N)=NS
          ENDIF
 50     CONTINUE
        NWUNKS=NWUNKS+MULTW(N)
 100  CONTINUE
      WRITE(9,*)'    TOTAL UNKNOWN NUMBER = ',NWUNKS
      WRITE(9,*)' '
      WRITE(9,*)'    NODE #        MULTIPLICITY'
      DO 60 J=1,NWNOD
        WRITE(9,*)J,MULTW(J)
 60   CONTINUE
      DO 70 N=1,NWNOD
        DO 65 J=1,MXWMLT+1
          WRITE(9,*)N,J,INSEG(J,N)
 65     CONTINUE
 70   CONTINUE
      RETURN
      END
```

A.34 EDGMUL

```
C=============================================================
      SUBROUTINE EDGMUL(IEDGF,MULT1,NEDGES,MULTE,IEDGE,IFACE,JE1,JE2)
C-------------------------------------------------------------
C  INPUT:
C  IEDGF FROM ROUTINE EDGFAC CONTAINS THE FACES CONNECTED TO EACH EDGE.
C  MULT1= THE MAXIMUM MULTIPLICITY OF ANY EDGE +1.
C  NEDGES= THE NUMBER OF EDGES.
C  MULTE IS THE MULTIPLICITY OF EDGE IEGDE.
C  IEDGE IS THE EDGE NUMBER.
C  IFACE IS THE FACE NUMBER.
C  OUTPUT:JE1 JG2
C  IF IFACE IS THE LOWEST NUMBERED FACE ATTACHED TO IEDGE THEN
C    JE1=1 AND JE2=MULTE
C  ELSEIF IFACE IS THE ITH FACE ATTACHEL TO IEDGE THEN
C    JE1=JE2=I-1
C-----------------------------------------------------------------
      INTEGER IEDGF(MULT1,NEDGES)
      IF(IEDGF(1,IEDGE).EQ.IFACE)THEN
        JE1=1
        JE2=MULTE
      ELSE
        M1=MULTE+1
        DO 10 I=2,M1
          IF(IFACE.EQ.IEDGF(I,IEDGE))THEN
            I1=I-1
            JE1=I1
            JE2=I1
            GO TO 11
          ENDIF
 10     CONTINUE
 11     CONTINUE
      ENDIF
      RETURN
      END
```

A.35 BCUMUL

```
C=====================================================================
      SUBROUTINE BCUMUL(NCONN,INDSUM,NEDGES)
C--------------------------------------------------------------------
C CUMULATE MULTIPLICITY OF EDGE
C INPUT:
C  NEDGES = THE NUMBER OF EDGES.
C  IE = A SPECIFIC EDGE NUMBER 1.LE.IE.LE.NEDGES.
C  NCONN(I,J) I=1,2,3: THE JTH EDGE RUNS FROM NODE NCONN(1,J) TO
C     NCONN(2,J) AND HAS MULTIPLICITY NCONN(3,J) (AFTER ACCOUNTING
C     FOR ALL GROUND PLANE ATTACHMENTS).
C
C OUTPUT:
C  IND = THE SUM OF THE EDGE MULTIPLICITIES UP TO (BUT NOT INCLUDING)
C     THE CURRENT EDGE(IE).
C--------------------------------------------------------------------
      DIMENSION NCONN(3,NEDGES),INDSUM(NEDGES)
      INDSUM(1)=0
      DO 10 I=2,NEDGES
      INDSUM(I)=NCONN(3,I-1)+INDSUM(I-1)
 10   CONTINUE
      RETURN
      END
```

A.36 FACEDG

```
C=====================================================================
      SUBROUTINE FACEDG(NFACES,NBOUND,IFACE,IEDG)
C--------------------------------------------------------------------
C MAPPING FROM FACE TO EDGE
      INTEGER NBOUND(3,NFACES),IEDG(3)
      DO 2 I=1,3
2      IEDG(I)=NBOUND(I,IFACE)
      RETURN
      END
```

A.37 FACVTX

```
C=====================================================================
      SUBROUTINE FACVTX(NCONN,NEDGES,IE,NV)
```

```
C-----------------------------------------------------------------------
C MAPPING FROM FACE TO VERTEX
      INTEGER NCONN(3,NEDGES),IE(3),NV(3)
      IF(NCONN(1,IE(2)).EQ.NCONN(1,IE(3)).OR.NCONN(1,IE(2)).EQ.NCONN(2,
     $IE(3)))THEN
        NV(1)=NCONN(1,IE(2))
      ELSE
        NV(1)=NCONN(2,IE(2))
      ENDIF
      IF(NCONN(1,IE(1)).EQ.NCONN(1,IE(3)).OR.NCONN(1,IE(1)).EQ.NCONN(2,
     $IE(3)))THEN
        NV(2)=NCONN(1,IE(1))
      ELSE
        NV(2)=NCONN(2,IE(1))
      ENDIF
      IF(NCONN(1,IE(1)).EQ.NCONN(1,IE(2)).OR.NCONN(1,IE(1)).EQ.NCONN(2,
     $IE(2)))THEN
        NV(3)=NCONN(1,IE(1))
      ELSE
        NV(3)=NCONN(2,IE(1))
      ENDIF
      RETURN
      END
```

A.38 VTXCRD

```
C=======================================================================
      SUBROUTINE VTXCRD(DATNOD,NNODES,N,DN)
C-----------------------------------------------------------------------
C MAPPING FROM VERTEX TO COORDINATE
      DIMENSION DATNOD(3,NNODES),N(3),DN(3,3)
      DO 2 I=1,3
      DO 2 J=1,3
2       DN(I,J)=DATNOD(J,N(I))
      RETURN
      END
```

A.39 WIRMAN

```
C=======================================================================
      SUBROUTINE WIRMAN(IFREQ,CZ,CV,NUNKNT,NUNKNB,NWNOD,NWSEG,NWUNKS,
```

```
     &  WNODE,MULTW,NSEGC,WSEGH,RAD,INSEG,WIRSUM,DATNOD,
     &  NCONN,NBOUND,NNODES,NEDGES,NFACES,IEDGF,MULT1,INDSUM,NJCT,MNJUN,
     &  NWJUN,NBJUN,NJFACE,MNJFACE,MIFACE,ANG,MXWMLT,IPAT)
C-----------------------------------------------------------------------
*  MXUNKN = MAXIMUM NUMBER OF UNKNOWNS EXPECTED.                        *
*  MXWNOD = MAXIMUM NUMBER OF WIRE NODES.                               *
*  MXWMLT = MAXIMUM MULTIPLICITY THAT ANY WIRE NODE MAY HAVE.           *
*  MXWSEG = MAXIMUM NUMBER OF WIRE SEGMENTS.                            *
*  MXWZN  = MAXIMUM NUMBER OF LUMPED IMPEDENCES ON WIRES.               *
*  MXWVLT = MAXIMUM NUMBER OF DELTA GAP VOLTAGE SOURCES ON THE WIRES.   .
*  MXFREQ = MAXIMUM NUMBER OF FREQUENCIES EXPECTED.                     *
*  MXCIT=MAXIMUM NUMBER OF EXCITATIONS ASSUMED THE SAME FOR ALL FREQS.  *
*  MXCIV=MAXIMUM NUMBER OF VOLTAGE EXCITATIONS.                         *
*  MXCIP=MAXIMUM NUMBER OF PLANE WAVE EXCITATIONS.                      *
C-----------------------------------------------------------------------
C
C PARAMETERS ASSOCIATE WITH JUNCTIONS
C
      REAL ANG(MNJUN,MNJFACE)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &      NWJUN(MNJUN)
C
      INTEGER IEDGF(MULT1,NEDGES)
      DIMENSION INDSUM(NEDGES)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IM(3)
      DIMENSION DATNOD(3,NNODES),TMAT(3,3),SM(3)
      DIMENSION WNODE(3,NWNOD),WSEGH(3,NWSEG),RAD(NWSEG)
      INTEGER MULTW(NWNOD),NSEGC(2,NWSEG),
     >        INSEG(MXWMLT+1,NWNOD),WIRSUM(NWNOD)
      COMPLEX CZ(NUNKNT,NUNKNT),CV(NUNKNT)
      COMMON/WIRE/IQUADW
      COMMON/WIRSLF/IQWS
      IQUADW=4
      IQWS=8
C
      CALL WCUMUL(NWNOD,NUNKNB,MULTW,WIRSUM)
      CALL  MTXWIR(MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,
     >      NSEGC,WSEGH,RAD,INSEG,CZ,CV,WIRSUM,DATNOD,NCONN,NBOUND,
     $      NNODES,NEDGES,NFACES,IEDGF,MULT1,INDSUM,NJCT,MNJUN,NWJUN,
     $      NBJUN,NJFACE,MNJFACE,MIFACE,ANG,IPAT)
      RETURN
      END
```

A.40 MTXWIR

```
C=================================================================
      SUBROUTINE MTXWIR(MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,
     >      NSEGC,WSEGH,RAD,INSEG,CZ,CV,WIRSUM,DATNOD,NCONN,NBOUND,
     $      NNODES,NEDGES,NFACES,IEDGF,MULT1,INDSUM,NJCT,MNJUN,NWJUN,
     $      NBJUN,NJFACE,MNJFACE,MIFACE,ANG,IPAT)
C-----------------------------------------------------------------
C FILL MATRIX ELEMENTS WHICH SOURCE POINT ON WIRE
C PARAMETERS ASSOCIATE WITH JUNCTIONS
C
      REAL ANG(MNJUN,MNJFACE)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &      NWJUN(MNJUN)
C
      INTEGER IEDGF(MULT1,NEDGES)
      DIMENSION INDSUM(NEDGES)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IM(3)
      DIMENSION DATNOD(3,NNODES),TMAT(3,3),SM(3)
C
      DIMENSION WNODE(3,NWNOD),MULTW(NWNOD),NSEGC(2,NWSEG),
     >         WSEGH(3,NWSEG),RAD(NWSEG),INSEG(MXWMLT+1,NWNOD)
      INTEGER WIRSUM(NWNOD)
      COMPLEX CZ(NUNKNT,NUNKNT),CV(NUNKNT)
      REAL LAMBDA,MU,K,IMP
C
*  DATA PASSED INTO WSOLTN FROM WINDAT
C
      SAVE /WAVE/,/PARAM/,/INC/,/MEDIUM/
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/PARAM/THETA,PHI,IFIELD
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/F/FREQ
C
      CALL ZWW(MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,NSEGC,
     >     WSEGH,RAD,INSEG,CZ,CV,WIRSUM,NWJUN,MNJUN)
C
      CALL ZBW(MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,NSEGC,
     $   WSEGH,RAD,INSEG,CZ,WIRSUM,DATNOD,NCONN,NBOUND,NNODES,NEDGES,
     $   NFACES,IEDGF,MULT1,INDSUM,NJCT,MNJUN,MNJFACE,ANG,NJFACE,MIFACE
     $   ,NWJUN,NBJUN)
C
 40     CONTINUE
 499  CONTINUE
```

```
      RETURN
      END
```

A.41 ZWW

```
C==================================================================
      SUBROUTINE ZWW(MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,NSEGC,
     >     WSEGH,RAD,INSEG,CZ,CV,WIRSUM,NWJUN,MNJUN)
C-----------------------------------------------------------------
C FILL MATRIX ELEMENTS WHICH SOURCE AND MATCHING POINTS ON WIRE
C
* INPUT:
*  MXWMLT = MAXIMUM MULTIPLICITY THAT ANY WIRE NODE MAY HAVE.
*  NWNOD  = NUMBER OF WIRE NODES.
*  NWSEG  = NUMBER OF WIRE SEGMENTS.
*  NUNKNB = NUMBER OF BODY UNKNOWNS.
*  NUNKNT = TOTAL NUMBER OF UNKNOWNS(BODY AND WIRE).
*  WNODE(I,J) I=1,2,3 CONTAINS THE X,Y,Z COORDINATES OF THE JTH WIRE
*  NODE.
*  MULTW(N) CONTAINS THE MULTIPLICITY OF THE NTH NODE.
*  NSEGC(I,J):THE JTH WIRE SEGMENT RUNS FROM NSEGC(1,J) TO NSEGC(2,J).
*  WSEGH(I,J) I=1,2,3 CONTAINS THE X,Y,Z COORDINATES OF THE MIDPOINT OF
*  JTH WIRE SEGMENT.
*  RAD(N) CONTAINS THE RADIUS OF THE NTH WIRE SEGMENT.
*  INSEG(M,N) M=1,...,MULTW(N) ARE THE SEGMENTS (IN INCREASING
*  ORDER) ATTATCHED TO THE NTH WIRE NODE.
*  NWCZN = THE NUMBER OF LUMPED IMPEDENCE LOADS ON THE WIRE.
*  IWCZN(1,I) CONTAINS THE NODE LOCATION OF THE ITH IMPEDENCE LOAD,
*  IWCZN(2,I)=1 IF THE LOAD IS ON THE FIRST NODE OF THE SEGMENT
*             2 IF THE LOAD IS ON THE SECOND NODE OF THE SEGMENT
*  I=1,...,NWCZN.
*  CWZN(I) CONTAINS THE VALUE OF THE COMPLEX LUMPED IMPEDENCE FOR THE
*  IWCZN(1,I)TH NODE, I=1,...,NWCZN.
*  NWVLT = THE NUMBER OF DELTA GAP VOLTAGE SOURCES ON THE WIRES.
*  IWVLT(1,I) CONTAINS THE NODE LOCATION OF THE ITH DELTA GAP VOLTAGE
*  SOURCE ON THE WIRES.
*  IWVLT(2,I)=1 IF THE SOURCE IS LOCATED ON THE FIRST NODE
*             2 IF THE SOURCE IS LOCATED ON THE 2ND NODE OF THE SEGMENT
*  CWVLT(I) CONTAINS THE VALUE OF THE COMPLEX DELTA GAP VOLTAGE
*  SOURCE OF THE IWVLT(1,I)TH NODE. A PASSIVE SIGN CONVENTION IS  WITH
*  RESPECT TO THE CURRENT IN THE DIRECTION OF THAT SEGMENT.
*  CZ THE IMPEDANCE MATRIX DIMENSIONED NUNKNT*NUNKNT
*  CV IS THE VOLTAGE FORCING FUNCTION VECTOR DIMENSIONED NUNKNT
```

```
* OUTPUT:
*  THE PORTION OF THE IMPEDANCE MATRIX ASSOCIATED WITH THE WIRE WIRE
*  COUPLING IS FILLED AND ALSO THE WIRE PORTION OF THE FORCING VECTOR IS
*  FILLED.
*  CZ(MM,NN)=J*OMEGA*(VAP(M,N) DOT VLP(M,N)+VAM(M,N) DOT VLM(M))
*            -(SPOTP(M,N)-SPOTM(M,N))
*  CV(MM)=VEP(M) DOT VLP(M)+VEM(M) DOT VLM(M) -ANY WIRE VOLTAGE SOURCE
*  MM=M+NUNKNB NN=N+NUNKNB
*  WHERE
*  VAP(M,N) AND VAM(M,N) ARE THE VECTOR POTENTIALS DUE TO THE
*  N TH WIRE BASIS FUNCTIONS EVALUATED AT THE + AND - CENTROIDS
*  OF THE M TH WIRE BASIS FUNCTION.
*  SPOTP(M,N) AND SPOTM(M,N) ARE THE SCALAR POTENTIALS DUE TO
*  THE N TH WIRE BASIS FUNCTION EVALUATED AT THE + AND THE -
*  CENTROIDS OF THE M TH WIRE BASIS FUNCTION.
*  N=1,...,NWUNKS M=1,...,NWUNKS
*  VLP(M) IS THE VECTOR WHICH RUNS FROM THE THE BEGINNING OF
*  THE + SEGMENT TO THE CENTROID OF THE + SEGMENT .THIS + SEGMENT IS THE
*  +  SEGMENT ASSOCIATED WITH THE M TH BASIS FUNCTION.
*  VLM(M) ISM NTHE VECTOR WHICH RUNS FROM THE - CENTROID OF THE M TH
*  BASIS FUNCTION TO THE ENDPOINT OF THAT SEGMENT.
C
C-----------------------------------------------------------------
      DIMENSION WNODE(3,NWNOD),MULTW(NWNOD),NSEGC(2,NWSEG),
     >          WSEGH(3,NWSEG),RAD(NWSEG),INSEG(MXWMLT+1,NWNOD),
     >          RMK(3),SH(3),RSK(3),T(3)
      COMPLEX CZ(NUNKNT,NUNKNT),CV(NUNKNT),
     >        CSPW,HTHETA,HPHI,ETHETA,EPHI,EX,EY,EZ,ANS(3),
     >        SPOT,VAP(3),VAM(3),SSPOT,VA(3),CETEMP,EDOTT,CARG,CTEMP
     >        ,CKRED,CKTOT,CKSELF,CANS
      INTEGER WIRSUM(NWNOD),NWJUN(MNJUN)
      REAL LAMBDA,K,MU,IMP
      EXTERNAL CKRED,CKTOT,CKSELF
      LOGICAL LOWS,LOWM,PLUS
      SAVE /WAVE/,/PARAM/,/INC/,/MEDIUM/,/WKERNL/,/WIRE/,/WKER/
      COMMON/POT/NM,NS,DEL,DELS,DELH,DELRH,RVPW,CSPW,RADMKS
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/PARAM/THETA,PHI,NFIELD
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/WKERNL/RSK,SH,RMK,RADSK,RADSKS
      COMMON/WKER/DPAR,RHO,RHOPR,RHOPRS,RHOMRS
      COMMON/WIRE/IQUADW
      COMMON/WIRSLF/IQWS
C
```

```
* SET CONSTANTS.
C
      IQUAD=IQUADW
      IQUAWS=IQWS
      PI4=4.*PI
      RVPW=MU/PI4
      CSPW=CMPLX(0.,1./(OMEGA*EPSLON*PI4))
      CTHETA=COS(THETA)
      STHETA=SIN(THETA)
      CPHI=COS(PHI)
      SPHI=SIN(PHI)
C
* CARTESIAN COMPONENTS OF THE INCIDENT FIELD ARE:
C
      EX=ETHETA*CTHETA*CPHI-EPHI*SPHI
      EY=ETHETA*CTHETA*SPHI+EPHI*CPHI
      EZ=-ETHETA*STHETA
C
* LOOP OVER THE SOURCE SEGMENTS.
C
      DO 1000 NS=1,NWSEG
        IF(NS.EQ.1.OR.NFIELD.LE.1)THEN
        RADSK=K*RAD(NS)
        RADSKS=RADSK*RADSK
        DELRH=15.*RADSK
C
* OBTAIN K* THE COORDINATES OF THE SOURCE SEGMENT CENTROID
C
          NSF=NSEGC(1,NS)
          NST=NSEGC(2,NS)
          DO 2 J=1,3
            RSK(J)=K*WSEGH(J,NS)
            SH(J)=K*(WNODE(J,NST)-WNODE(J,NSF))
 2        CONTINUE
          DEL=SQRT(SH(1)*SH(1)+SH(2)*SH(2)+SH(3)*SH(3))
          DELS=DEL*DEL
          DELH=.5*DEL
          DO 4 J=1,3
            SH(J)=SH(J)/DEL
 4        CONTINUE
C
* LOOP OVER THE MATCH SEGMENTS.
C
          DO 500 NM=1,NWSEG
            RADMK=K*RAD(NM)
```

```
          RADMKS=RADMK*RADMK
C
* OBTAIN COORDINATES OF TEST VECTOR AND MATCH SEGMENT CENTROID TIMES K.
C
          NMF=NSEGC(1,NM)
          NMT=NSEGC(2,NM)
          DO 5 J=1,3
            T(J)=.5*(WNODE(J,NMT)-WNODE(J,NMF))
           RMK(J)=K*WSEGH(J,NM)
5         CONTINUE
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
      CALL POTWIR(SSPOT,VAP,VAM,0)
          IV=0
C
* LOOP OVER NODES ATTACHED TO THE SOURCE SEGMENT.
C
          DO 400 JNS=1,2
            NODES=NSEGC(JNS,NS)
            MULTS=MULTW(NODES)
            IF(MULTS.GT.0)THEN
C
* COMPUTE COLUMN INDEX FOR SOURCE SEGMENT.
C
              INDC=WIRSUM(NODES)
C
*  DETERMINE WHETHER SEGMENT NS IS THE LOWEST SEGMENT ATTACHED TO NODE
*  NODES.LOOP OVER THE NUMBER OF SEGMENTS ATTACHED TO NS AT NODE NODES.
C
              CALL NODMUL(INSEG,MXWMLT,NWNOD,NODES,MULTS,NS,JS1,JS2,
     >                   LOWS)
      IF(LOWS.AND.NODES.EQ.NWJUN(MNJUN)) THEN
      JS1=1
      JS2=1
      LOWS=.FALSE.
      ENDIF
              DO 300 J=JS1,JS2
                ICOL=INDC+J
                IV=IV+1
                IF(NODES.EQ.NSEGC(2,NS))THEN
                  PLUS=.TRUE.
                ELSE
                  PLUS=.FALSE.
                ENDIF
```

```
                IF(LOWS)THEN
C
* OBTAIN THE ATTACHED SEGMENT.
C
                  NSEGAS=INSEG(J+1,NODES)
C
* SGN=+1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE SAME DIRECTION,
* SGN=-1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE OPPOSITE DIRECTION
C
                  IF(NSEGC(2,NS).EQ.NSEGC(1,NSEGAS).OR.
     >               NSEGC(1,NS).EQ.NSEGC(2,NSEGAS))THEN
                    SGN=1.
                  ELSE
                    SGN=-1.
                  ENDIF
                ELSE
                  SGN=1.
                ENDIF
C
C
* COMPUTE APPROPRIATE VECTOR AND SCALAR POTENTIALS.
C
                IF(PLUS)THEN
C
C FOR PLUS SOURCE SEGMENT SET SIGN= (-1) TO VECTOR AND SCALAR POTENTIALS
C
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=-1.
                  DO 30 JJ=1,3
                    VA(JJ)=VAP(JJ)*SGN
 30               CONTINUE
                  SPOT=SSPOT*SGN
                ELSE
C
C FOR MINUS SOURCE SEGMENT SET SIGN= (+1) TO VECTOR POTENTIAL AND
C (-1) TO SCALAR POTENTIALS
C
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=1.
                  DO 40 JJ=1,3
                    VA(JJ)=VAM(JJ)*SGN
 40               CONTINUE
                  SPOT=-SSPOT*SGN
                ENDIF
                CTEMP=(VA(1)*T(1)+VA(2)*T(2)+VA(3)*T(3))*
     >                  CMPLX(0.,OMEGA)
                IF(NS.EQ.1 .AND.IV.EQ.1)THEN
```

```
C
* COMPUTE QUANTIES ASSOCIATED WITH THE INCIDENT FIELD.
C
                  ARGMNT=(RMK(1)*CPHI+RMK(2)*SPHI)*STHETA+
     >                    RMK(3)*CTHETA
                  CARG=CMPLX(0.,ARGMNT)
                  EDOTT=EX*T(1)+EY*T(2)+EZ*T(3)
                  CETEMP=EDOTT*CEXP(CARG)
                ENDIF
C
* LOOP OVER THE NODES ATTACHED TO THE MATCH SEGMENT.
C
                DO 250 JMN=1,2
                  NODEM=NSEGC(JMN,NM)
                  MULTM=MULTW(NODEM)
                  IF(MULTM.GT.0)THEN
C
* COMPUTE ROW INDEX FOR SOURCE SEGMENT.
C
                    INDR=WIRSUM(NODEM)
C
* DETERMINE WHETHER SEGMENT NM IS THE LOWEST SEGMENT ATTACHED
* TO SEGMENT NM AT NODE NODEM.LOOP OVER THE NUMBER OF SEGMENTS ATTACHED
* TO SEGMENT NM AT NODE NODEM.
C
                    CALL NODMUL(INSEG,MXWMLT,NWNOD,NODEM,MULTM,NM,
     >                         JM1,JM2,LOWM)
      IF(LOWM.AND.NODEM.EQ.NWJUN(MNJUN)) THEN
      JM1=1
      JM2=1
      LOWM=.FALSE.
      ENDIF
                    DO 200 JM=JM1,JM2
C
* DETERMINE WHETHER SEGMENT IS A PLUS OR MINUS SEGMENT.
C
                      IF(NODEM.EQ.NSEGC(2,NM))THEN
                        SGN1=1.
                      ELSE
                        SGN1=-1.
                      ENDIF
                      IF(LOWM)THEN
C
* CASE: SEGMENT NM IS THE LOWEST NUMBERED SEGMENT ATTACHED TO NODE
* NODEM. DIRECTION OF THE BASIS FUNCTION IS DETERMINED BY THE ATTACHED
```

```
* SEGMENT. OBTAIN ATTACHED SEGMENT.
C
                          NSEGAM=INSEG(JM+1,NODEM)
                          IF(NSEGC(2,NM).EQ.NSEGC(1,NSEGAM).OR.
     >                       NSEGC(1,NM).EQ.NSEGC(2,NSEGAM))THEN
                            SGN=1.
                          ELSE
                            SGN=-1.
                          ENDIF
                        ELSE
                          SGN=1.
                        ENDIF
C CHECK IF THIS IS A JUNCTION NODE
      IF(NODEM.EQ.NWJUN(MNJUN))THEN
C CHECK IF THIS IS A PLUS SEGMENT
                        IF(NODEM.EQ.NSEGC(2,NM))THEN
C
C FOR PLUS MATCHING SEGMENT SET SIGN= (-1) TO VECTOR POTENTIAL AND
C (+1) TO SCALAR POTENTIALS
C
C FOR MINUS MATCHING SEGMENT SET SIGN= (+1) TO VECTOR POTENTIAL AND
C (+1) TO SCALAR POTENTIALS
C
      SGN=-1.
      SGN1=1.
      ELSE
      SGN=1.
      SGN1=-1.
      ENDIF
      ENDIF
C
                        IROW=INDR+JM
                        IF(NS.EQ.1.AND.IV.EQ.1)CV(IROW)=
     >                                           CV(IROW)+SGN*CETEMP
                       IF(NFIELD.EQ.1)CZ(IROW,ICOL)=
     >                                 CZ(IROW,ICOL)+SGN*(CTEMP-SPOT*SGN1)
 200                  CONTINUE
                    ENDIF
 250              CONTINUE
 300            CONTINUE
              ENDIF
 400        CONTINUE
 500      CONTINUE
        ENDIF
 1000 CONTINUE
```

```
      RETURN
      END
```

A.42 ZBW

```
C=========================================================================
      SUBROUTINE ZBW(MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,NSEGC,
     $   WSEGH,RAD,INSEG,CZ,WIRSUM,DATNOD,NCONN,NBOUND,NNODES,NEDGES,
     $   NFACES,IEDGF,MULT1,INDSUM,NJCT,MNJUN,MNJFACE,ANG,NJFACE,MIFACE
     $   ,NWJUN,NBJUN)
C-----------------------------------------------------------------------
C THIS ROUTINE FILL OUT THE MATRIX ELEMENTS OF ZBW WHICH IS SOURCE POINT
C  ON THE WIRE AND MATCH POINT ON THE BODY
C PARAMATERS ASSOCIATE WITH JUNCTION PART
C
      REAL ANG(MNJUN,MNJFACE),XM(3),YM(3),ZM(3),VMJUN(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &       NWJUN(MNJUN),NM(3)
C
        INTEGER IEDGF(MULT1,NEDGES)
      DIMENSION INDSUM(NEDGES)
      DIMENSION WNODE(3,NWNOD),MULTW(NWNOD),NSEGC(2,NWSEG),
     >           WSEGH(3,NWSEG),RAD(NWSEG),INSEG(MXWMLT+1,NWNOD),
     >           RMK(3),SH(3),RSK(3),T(3)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IM(3)
      DIMENSION DATNOD(3,NNODES),TMAT(3,3),SM(3)
      COMPLEX CZ(NUNKNT,NUNKNT),
     >        CSPW,HTHETA,HPHI,ETHETA,EPHI,EX,EY,EZ,ANS(3),
     >        SPOT,VAP(3),VAM(3),SSPOT,VA(3),CETEMP,EDOTT,CARG,CTEMP
     >        ,CKRED,CKTOT,CKSELF,CANS,CJWEMP,CX
      INTEGER WIRSUM(NWNOD),IGNDP(3)
      REAL LAMBDA,K,MU,IMP,DM(3,3),DLM(3),DMC(3)
      EXTERNAL CKRED,CKTOT,CKSELF
      LOGICAL LOWS,LOWM,PLUS
      SAVE /WAVE/,/PARAM/,/INC/,/MEDIUM/,/WKERNL/,/WIRE/,/WKER/
      COMMON/POT/NFM,NS,DEL,DELS,DELH,DELRH,RVPW,CSPW,RADMKS
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/PARAM/THETA,PHI,NFIELD
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/WKERNL/RSK,SH,RMK,RADSK,RADSKS
      COMMON/WKER/DPAR,RHO,RHOPR,RHOPRS,RHOMRS
      COMMON/WIRE/IQUADW
```

```
      COMMON/WIRSLF/IQWS
      COMMON/GPLANE/NGNDP,IGNDP
C
* SET CONSTANTS.
C
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      NFM=0
      IQUAD=IQUADW
      IQUAWS=IQWS
      PI4=4.*PI
      RVPW=MU/PI4
      CSPW=CMPLX(0.,1./(OMEGA*EPSLON*PI4))
C
* LOOP OVER THE SOURCE SEGMENTS OF THE WIRE
C
      CALL BCUMUL(NCONN,INDSUM,NEDGES)
      DO 1000 NS=1,NWSEG
        IF(NS.EQ.1.OR.NFIELD.LE.1)THEN
        RADSK=K*RAD(NS)
        RADSKS=RADSK*RADSK
        DELRH=15.*RADSK
C
* OBTAIN K* THE COORDINATES OF THE SOURCE SEGMENT CENTROID
C
          NSF=NSEGC(1,NS)
          NST=NSEGC(2,NS)
          DO 2 J=1,3
            RSK(J)=K*WSEGH(J,NS)
            SH(J)=K*(WNODE(J,NST)-WNODE(J,NSF))
 2        CONTINUE
          DEL=SQRT(SH(1)*SH(1)+SH(2)*SH(2)+SH(3)*SH(3))
          DELS=DEL*DEL
          DELH=.5*DEL
          DO 4 J=1,3
            SH(J)=SH(J)/DEL
 4        CONTINUE
C
C LOOP OVER FACE NUMBERS OF THE MATCH TRIANGLES OF THE BODY
          DO 500 IFM=1,NFACES
      IIM=1
C OBTAIN THE EDGES OF THE MATCH TRIANGLE
            CALL FACEDG(NFACES,NBOUND,IFM,IM)
C OBTAIN THE VERTICES OF THE MATCH TRIANGLE
            CALL FACVTX(NCONN,NEDGES,IM,NM)
C OBTAIN THE COORDINATES OF THE MATCH TRIANGLE'S VERTICIES
```

```
            CALL VTXCRD(DATNOD,NNODES,NM,DM)
      DO 14 J=1,3
C CALCULATE THE CENTROID OF THE MATCH TRIANGLE
      DMC(J)=(DM(1,J)+DM(2.J)+DM(3,J))/3
C RMK(J) IS THE MATCH POINT
14        RMK(J)=K*DMC(J)
      DO 6 I=1,3
      DO 6 J=1,3
C TESTING VECTOR = 0.5*THE VECTOR RUNNING FROM THE ITH VERTICE TO CENTROID
6           TMAT(I,J)=(DMC(J)-DM(I,J))/2.
            DO 8 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
C COMPUTE THE EDGE LENGTH OF THE MATCH TRIANGLE
      DO 7 J=1,3
7      DLM(J)=DM(IM1,J)-DM(IP1,J)
8      SM(I)=SIZE(DLM(1),DLM(2),DLM(3))
C------------------------------------------------------------------
C IF NJCT=0, NO WIRE JUNCTION WITH BODY
C IF NJCT=1, CHECK IF ANY JUNCTION IN THIS MATCH TRIANGLE
C IF JMF=0, NO JUNCTION IN THIS MATCH TRIANGLE
C IF JMF=N, N=1,2,3, FIND OUT ASSOCIATED PARAMETERS
C
      IF(NJCT.EQ.1)THEN
C
C TO FIND PARAMATERS ASSOCIATE WITH THIS JUNCTION
C
      CALL JUNPAR(JMF,DM,NM,IFM,ANGM,VMJUN,JMROW,
     &      WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C
C ANGM IS THE ANGULAR DISTRIBUTION COEFFICIENCY OF MATCH TRIANGLE
C
      ELSE
      JMF=0
      ENDIF
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
      CALL POTWIR(SSPOT,VAP,VAM,0)
            IV=0
C
* LOOP OVER NODES ATTACHED TO THE SOURCE SEGMENT
C
            DO 400 JNS=1,2
              NODES=NSEGC(JNS,NS)
```

```
              MULTS=MULTW(NODES)
              IF(MULTS.GT.0)THEN
C
* COMPUTE COLUMN INDEX FOR SOURCE SEGMENT.
C
                INDC=WIRSUM(NODES)
C
*  DETERMINE WHETHER SEGMENT NS IS THE LOWEST SEGMENT ATTACHED TO NODE
*  NODES.LOOP OVER THE NUMBER OF SEGMENTS ATTACHED TO NS AT NODE NODES.
C
C CHECK IF SOURCE POINT IS A JUNCTION POINT
                CALL NODMUL(INSEG,MXWMLT,NWNOD,NODES,MULTS,NS,JS1,JS2,
     >                    LOWS)
      IF(LOWS.AND.NODES.EQ.NWJUN(MNJUN)) THEN
      JM1=1
      JM2=1
      LOWS=.FALSE.
      ENDIF
                DO 300 J=JS1,JS2
                  ICOL=INDC+J
                  IV=IV+1
                  IF(NODES.EQ.NSEGC(2,NS))THEN
                    PLUS=.TRUE.
                  ELSE
                    PLUS=.FALSE.
                  ENDIF
                  IF(LOWS)THEN
C
* OBTAIN THE ATTACHED SEGMENT.
C
                    NSEGAS=INSEG(J+1,NODES)
C
* SGN=+1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE SAME DIRECTION,
* SGN=-1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE OPPOSITE DIRECTION
C
                    IF(NSEGC(2,NS).EQ.NSEGC(1,NSEGAS).OR.
     >                 NSEGC(1,NS).EQ.NSEGC(2,NSEGAS))THEN
                      SGN=1.
                    ELSE
                      SGN=-1.
                    ENDIF
                  ELSE
                    SGN=1.
                  ENDIF
C
```

```
* COMPUTE APPROPRIATE VECTOR AND SCALAR POTENTIALS.
C
                  IF(PLUS)THEN
C FOR THE JUNCTION POINT SET SGN=-1 TO THE PLUS SEGMENT
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=-1.
                    DO 30 JJ=1,3
C VECTOR POTENTIAL
                      VA(JJ)=VAP(JJ)*SGN
 30                 CONTINUE
C SCALAR POTENTIAL
                    SPOT=SSPOT*SGN
                  ELSE
C FOR THE JUNCTION SET SGN=1 TO THE MINUS SEGMENT
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=1.
                    DO 40 JJ=1,3
C VECTOR POTENTIAL
                      VA(JJ)=VAM(JJ)*SGN
 40                 CONTINUE
C SCALAR POTENTIAL
                    SPOT=-SSPOT*SGN
                  ENDIF
C
C ZJW : SOURCE POINT ON THE WIRE, MATCH POINT ON THE JUNCTION TRIANGLE
C
      IF(JMF.NE.0) THEN
C VECTOR POTENTIAL DOT WITH TESTING VECTOR
      CJWEMP=(VA(1)*VMJUN(1)+VA(2)*VMJUN(2)+VA(3)*VMJUN(3))*
     &      CMPLX(0.,OMEGA)
C SET + TO VECTOR POTENTIAL AND - TO SCALAR POTENTIAL
        CX=(CJWEMP-SPOT)*ANGM
      IF(NFIELD.EQ.1)CZ(JMROW,ICOL)=CZ(JMROW,ICOL)
     $ +CX
        ENDIF
C
C LOOP OVER THE EDGES OF THE MATCH TRIANGLE OF THE BODY
                  DO 100 IML=1,3
                    IF(NCONN(3,IM(IML)).GT.0)THEN
                      T1=TMAT(IML,1)
                      T2=TMAT(IML,2)
                      T3=TMAT(IML,3)
                      FLAG=1.
                      IF(IML.EQ.1)THEN
                        IF(NCONN(1,IM(1)).EQ.NM(3))FLAG=-1.
                      ELSEIF(IML.EQ.2)THEN
                        IF(NCONN(1,IM(2)).EQ.NM(1))FLAG=-1.
```

```
                          ELSE
                            IF(NCONN(1,IM(3)).EQ.NM(2))FLAG=-1.
                          ENDIF
                          CTEMP=(VA(1)*T1+VA(2)*T2+VA(3)*T3)*
     $                      CMPLX(0.,OMEGA)
                          MULTM=NCONN(3,IM(IML))
                          IF(MULTM.GT.0)THEN
                            IMM=IM(IML)
C FOR AN EDGE WITH MULTIPLICITY MULT, THE LOWEST NUMBERED FACE
C CONTRIBUTES TO MULT BASIS FUNCTIONS ASSOCIATED WITH THAT EDGE,
C WHILE EACH REMAINING FACE CONTRIBUTES TO ONE BASIS FUNCTION ASSOCIATED
C WITH THAT EDGE.
                            CALL EDGMUL(IEDGF,MULT1,NEDGES,MULTM,IMM,IFM,
     $JM1,JM2)
                                              INDM=INDSUM(IMM)
                            DO 50 JM=JM1,JM2
                              IROW=INDM+JM
                             CX=FLAG*(CTEMP-SPOT)*SM(IML)
                            IF(NFIELD.EQ.1)CZ(IROW,ICOL)=
     >                        CZ(IROW,ICOL)+CX
50                         CONTINUE
                          ENDIF
                        ENDIF
 100                  CONTINUE
 300                CONTINUE
                  ENDIF
 400            CONTINUE
 500          CONTINUE
            ENDIF
 1000 CONTINUE
      RETURN
      END
```

A.43 ZBB

```
C=====================================================================
       SUBROUTINE ZBB(DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,NEDGES,
     $       NFACES,NUNKNT,CZ,CV,INDSUM,NJCT,MNJUN,MNJFACE,NWNOD,WIRSUM,
     $       ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C---------------------------------------------------------------------
C  THIS ROUTINE FILLS THE BODY-BODY ELEMENTS OF THE IMPEDANCE MATRIX.
C  ZBBCZ(M,N)=L(M)*[J*OMEGA*(VAP(M,N)DOT VRCP(M)/2+VAM(M,N)DOT VRC(M,N)/2)
C                 -SPOTP(M,N)+SPOTM(M,N)]
```

```
C  CV(M)=L(M)*[VEP(M)DOT VRCP(M)/2+VEM(M)DOT VRCM(M)]
C  WHERE:
C  VAP(M,N) AND VAM(M,N) ARE THE VECTOR POTENTIALS DUE TO THE NTH BODY
C  BASIS FUNCTION EVALUATED AT THE + AND - CENTROIDS OF THE MTH BODY
C  BASIS FUNCTION.
C  L(M) IS THE LENGTH OF THE EDGE ASSOCIATED WITH THE MTH BASIS
C  FUNCTION TRIANGLES.
C  SPOTP(M,N) AND SPOTM(M,N) ARE THE SCALAR POTENTIALS DUE TO THE NTH
C  BASIS FUNCTION EVALUATED AT THE + AND - CENTROIDS OF THE MTH BASIS
C  FUNCTION TRIANGLES.
C  VRCP(M) AND VRCM(M) ARE THE COORDINATE VECTORS OF THE + AND -
C  CENTROIDS OF THE MTH BASIS FUNCTION TRIANGLES.
C  VEP(M) AND VEM(M) ARE THE ELECTRIC FIELD VECTORS EVALUATED AT THE +
C  AND - CENTROIDS OF THE MTH BASIS FUNCTION TRIANGLES. N=1,...,NUNKNB
C  M=1,...,NUNKNB, WHERE NUNKNB IS THE NUMBER OF BODY UNKNOWNS.
C
C INPUT:
C  DATNOD(I,J) I=1,2,3 ARE THE X,Y,Z COMPONENTS OF THE JTH VERTEX.
C  THE JTH EDGE RUNS FROM NCONN(1,J) TO NCONN(2,J). NCONN(3,J) IS THE
C  MULTIPLICITY OF THE JTH EDGE(I.E. THE NUMBER OF UNKNOWNS ASSOCIATED
C  WITH THAT EDGE.)
C  NBOUND(I,J) I=1,2,3 ARE THE 3 EDGES OF THE JTH FACE.
C  NNODES IS THE NUMBER OF NODES ON THE BODY.
C  NFACES IS THE NUMBER OF BODY FACES.
C  NUNKNT IS THE TOTAL NUMBER OF UNKNOWNS.
C  ALSO THE COMMON FIELDS /WAVE,PARAM,INC/ IN PARTICULAR NFIELD
C  COMPUTED IN SOLTN AND /MEDIUM/ COMPUTED IN INDATA ARE PASSED.
C OUTPUT:
C  IF NFIELD .LE. 1 BOTH CONTRIBUTIONS TO CZ AND CV ARE FILLED.
C  IF NFIELD .GT. 1 ONLY CONTRIBUTIONS TO CV ARE FILLED.
C----------------------------------------------------------------------
C PARAMATERS ASSOCIATE WITH JUNCTION PART
      REAL ANG(MNJUN,MNJFACE),VMJUN(3),VSJUN(3),H(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &       NWJUN(MNJUN),WIRSUM(NWNOD)
C
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IEDGF(MULT1,NEDGES),
     $       IM(3),IS(3),NS(3),NM(3),IGNDP(3)
      DIMENSION INDSUM(NEDGES),DN(3,3),DM(3,3),DMC(3),DLM(3),AL(3)
     $       ,SN(3),DLN(3),DATNOD(3,NNODES),TMAT(3,3),RK(3,3),RMK(3),
     $       SM(3),DL(3,3)
      COMPLEX CJBEMP,CBJEMP,CJETEMP,CJJEMP
     $,CZ(NUNKNT,NUNKNT),CV(NUNKNT),HTHETA,HPHI,ETHETA,EPHI,
     $EX,EY,EZ,EDOTT,CVPB,CSPB,C,CI(3),CA(3),CSJPOT,CSPOT.CFLAG,CARG,
     $CTEMP,CETEMP,CP(3),CPP,CMM,CAJ(3),CAJT(3),CAJ2(3),CAJT2(3)
```

```
C
C VARIABLES ASSOCIATED WITH IMAGE PATCH
     $,CII(3),CPPI,CMMI,CAI(3),CAJTI(3),C1(3),CAA(3,3)
C
      REAL LAMBDA,K,MU,IMP
      COMMON/PARA/DL,DET,H,AL
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/PARAM/THETA,PHI,NFIELD
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/GPLANE/NGNDP,IGNDP
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      CVPB=CMPLX(0.,IMP/(4.*PI))
      CSPB=CMPLX(0.,.5/(PI*OMEGA*EPSLON))
      CTHETA=COS(THETA)
      STHETA=SIN(THETA)
      CPHI=COS(PHI)
      SPHI=SIN(PHI)
      EX=ETHETA*CTHETA*CPHI-EPHI*SPHI
      EY=ETHETA*CTHETA*SPHI+EPHI*CPHI
      EZ=-ETHETA*STHETA
C
      DO 999 IFS=1,NFACES
      IIS=1
        IF(IFS.EQ.1.OR.NFIELD.LE.1)THEN
C OBTAIN THE EDGES OF THE SOURCE TRIANGLE
          CALL FACEDG(NFACES,NBOUND,IFS,IS)
C OBTAIN THE VERTICES OF THE SOURCE TRIANGLE
          CALL FACVTX(NCONN,NEDGES,IS,NS)
C OBTAIN THE COORDINATES OF THE SOURCE TRIANGLE'S VERTICIES
          CALL VTXCRD(DATNOD,NNODES,NS,DN)
      DO 2 I=1,3
      DO 2 J=1,3
2     RK(I,J)=K*DN(I,J)
      DO 88 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      DO 77 J=1,3
77    DLN(J)=DN(IM1,J)-DN(IP1,J)
88    SN(I)=SIZE(DLN(1),DLN(2),DLN(3))
C IF NJCT=0, NO JUNCTION CASE
C IF NJCT=1, CHECK IF ANY JUNCTION IN THIS SOURCE TRIANGLE
C IF JSF=0, NO JUNCTION IN THIS SOURCE TRIANGLE
C IF JSF=N, N=1,2,3, FIND OUT ASSOCIATED PARAMETERS
C
```

```
      IF(NJCT.EQ.1) THEN
C TO FIND PARAMATERS ASSOCIATE WITH THIS JUNCTION
      CALL JUNPAR(JSF,DN,NS,IFS,ANGS,VSJUN,JSCOL,
     &        WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C ANGS IS THE ANGULAR DISTRIBUTION COEFFICIENCY OF SOURCE TRIANGLE
C SN(JMF) IS THE LENGTH OF OPPOSITE EDGE
      IF(JSF.NE.0)      ANGS=ANGS/SN(JSF)
      ELSE
      JSF=0
      ENDIF
C
      DO 499 IFM=1,NFACES
      IIM=1
      IIV=1
C OBTAIN THE EDGES OF THE MATCH TRIANGLE
            CALL FACEDG(NFACES,NBOUND,IFM,IM)
C OBTAIN THE VERTICES OF THE MATCH TRIANGLE
            CALL FACVTX(NCONN,NEDGES,IM,NM)
C OBTAIN THE COORDINATES OF THE MATCH TRIANGLE'S VERTICIES
            CALL VTXCRD(DATNOD,NNODES,NM,DM)
C CALCULATE THE CENTROID OF THE MATCH TRIANGLE
      DO 4 J=1,3
      DMC(J)=(DM(1,J)+DM(2,J)+DM(3,J))/3.
C RMK(J) IS THE MATCH POINT
4      RMK(J)=K*DMC(J)
       DO 6 I=1,3
       DO 6 J=1,3
6            TMAT(I,J)=(DMC(J)-DM(I,J))/2.
      DO 8 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      DO 7 J=1,3
7     DLM(J)=DM(IM1,J)-DM(IP1,J)
8     SM(I)=SIZE(DLM(1),DLM(2),DLM(3))
C
C IF NJCT=0, NO JUNCTION CASE
C IF NJCT=1, CHECK IF ANY JUNCTION IN THIS MATCH TRIANGLE
C IF JMF=0, NO JUNCTION IN THIS MATCH TRIANGLE
C IF JMF=N, N=1,2,3, FIND OUT ASSOCIATED PARAMETERS
C
      IF(NJCT.EQ.1)THEN
C TO GET PARAMATERS ASSOCIATE WITH THIS JUNCTION
      CALL JUNPAR(JMF,DM,NM,IFM,ANGM,VMJUN,JMROW,
     &        WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C ANGM IS THE ANGULAR DISTRIBUTION COEFFICIENCY OF MATCH TRIANGLE
```

```
C
      ELSE
      JMF=0
      ENDIF
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
C CAA(I)= INTEGRAL OF ( XSI(I)*(EXP(-JKR)-XSING)/R D (XSI(I))
C D(XSI(I+1))) IF XSING=1 THEN +1/(2*AREA)*INTEGRAL OF XSI(I)/R
C D(S')  XSI(I),I=1,3 DENOTE ZETA, XSI AND ETA, XSING=0 OR 1
C DL(I,J) IS THE VECTOR FROM THE I+1TH VERTEX TO THE ITH VERTEX
C AL(I) IS THE LENGTH OF THE DL(I,J)
C
           CALL POTBOD(JSF,RK,RMK,C,CAA,CAJT,0)
      IF(JSF.NE.0) THEN
      ISL=JSF
C SET (+) TO CA (-) TO CAJT (+) TO CSJPOT
      FLAG=AL(JSF)
                 CFLAG=CVPB*FLAG
C
C CAA(J),J=1,3 ARE THE X,Y,Z COMPONENTS OF THE VECTOR PONTETIAL
C DUE TO THE TRIANGULAR BASIS FUNCTION
C CAA=(SGN)*MU*AL(I)/4*PI*(CI(I+1)*DL(I-1,J)-CI(I-1)*DL(I+1,J))
C CAJT(J) IS THE VECTOR POTENTIAL DUE TO THE JUNCTION PART OF
C THE JUNCTION BASIS FUNCTION
C CAJ(J) IS THE VECTOR POTENTIAL DUE TO THE JUNCTION
C BASIS FUNCTION
C SET (+) TO CA (-) TO CAJT (+) TO CSJPOT
C
      DO 29 J=1,3
29        CAJ(J)=(CFLAG*CAA(JSF,J)-CVPB*CAJT(J))
C
C SET (+) TO CA (-) TO CAJT (+) TO CSJPOT
C CSJPOT IS THE SCALAR POTENTIAL ASSOCIATED WITH THIS JUNCTION
C
                 CSJPOT=CSPB*C*AL(JSF)
      ENDIF
            IV=0
            DO 460 ISL=1,3
              ISS=IS(ISL)
              MULTS=NCONN(3,ISS)
              IF(MULTS.NE.0)THEN
                IF(ISL.EQ.1)THEN
                  FLAG=AL(1)
                  IF(NCONN(1,IS(1)).EQ.NS(3))FLAG=-FLAG
```

```
                ELSEIF(ISL.EQ.2)THEN
                  FLAG=AL(2)
                  IF(NCONN(1,IS(2)).EQ.NS(1))FLAG=-FLAG
                ELSE
                  FLAG=AL(3)
                  IF(NCONN(1,IS(3)).EQ.NS(2))FLAG=-FLAG
                ENDIF
                CFLAG=CVPB*FLAG
      IP1=MOD(ISL,3)+1
      IM1=MOD(IP1,3)+1
C
C CA(J),J=1,3 ARE THE X,Y,Z COMPONENTS OF THE VECTOR PONTETIAL
C CA=(SGN)*MU*AL(I)/4*PI*(CI(I+1)*DL(I-1,J)-CI(I-1)*DL(I+1,J))
C
      DO 9 J=1,3
9      CA(J)=CFLAG*CAA(ISL,J)
C
C CSPOT IS THE SCALAR POTENTIAL
C
                CSPOT=CSPB*FLAG*C
C
C FOR AN EDGE WITH MULTIPLICITY MULT, THE LOWEST NUMBERED FACE
C CONTRIBUTES TO MULT BASIS FUNCTIONS ASSOCIATED WITH THAT EDGE,
C WHILE EACH REMAINING FACE CONTRIBUTES TO ONE BASIS FUNCTION ASSOCIATED
C WITH THAT EDGE.
                CALL EDGMUL(IEDGF,MULT1,NEDGES,MULTS,ISS,IFS,JS1,JS2)
                         INDS=INDSUM(ISS)
                DO 450 JS=JS1,JS2
                  IV=IV+1
                  ICOL=INDS+JS
C
C ZJB : NO JUNCTION IN THIS SOURCE TRIANGLE,
C      HAS JUNCTION IN THIS MATCH TRIANGLE
C
      IF(JMF.NE.0) THEN
C VECTOR POTENTIAL DOT WITH TESTING VECTOR
      CJBEMP=CA(1)*VMJUN(1)+CA(2)*VMJUN(2)+CA(3)*VMJUN(3)
C SET + TO VECTOR POTENTIAL AND - TO SCALAR POTENTIAL
                    IF(NFIELD.EQ.1)CZ(JMROW,ICOL)=CZ(JMROW,ICOL)
     $ +(CJBEMP-CSPOT)*ANGM
      ENDIF
C
                   DO 100 IML=1,3
                     IF(NCONN(3,IM(IML)).GT.0)THEN
                       T1=TMAT(IML,1)
```

```
                    T2=TMAT(IML,2)
                    T3=TMAT(IML,3)
                    FLAG=1.
                    IF(IML.EQ.1)THEN
                      IF(NCONN(1,IM(1)).EQ.NM(3))FLAG=-1.
                    ELSEIF(IML.EQ.2)THEN
                      IF(NCONN(1,IM(2)).EQ.NM(1))FLAG=-1.
                    ELSE
                      IF(NCONN(1,IM(3)).EQ.NM(2))FLAG=-1.
                    ENDIF
C
                    IF(IFS.EQ.1 .AND. IV.EQ.1)THEN
                      ARGMNT=DMC(1)*STHETA*CPHI+DMC(2)*STHETA*SPHI
     $                       +DMC(3)*CTHETA
                      CARG=CMPLX(0.,K*ARGMNT)
                      EDOTT=EX*T1+EY*T2+EZ*T3
                      CETEMP=EDOTT*CEXP(CARG)
                    ENDIF
                    IF(NFIELD.EQ.1)CTEMP=CA(1)*T1+CA(2)*T2+CA(3)*T3
                    MULTM=NCONN(3,IM(IML))
                    IF(MULTM.GT.0)THEN
                      IMM=IM(IML)
C FOR AN EDGE WITH MULTIPLICITY MULT, THE LOWEST NUMBERED FACE
C CONTRIBUTES TO MULT BASIS FUNCTIONS ASSOCIATED WITH THAT EDGE,
C WHILE EACH REMAINING FACE CONTRIBUTES TO ONE BASIS FUNCTION ASSOCIATED
C WITH THAT EDGE.
                      CALL EDGMUL(IEDGF,MULT1,NEDGES,MULTM,IMM,IFM,
     $JM1,JM2)
                                        INDM=INDSUM(IMM)
                      DO 50 JM=JM1,JM2
                        IROW=INDM+JM
                        IF(NFIELD.EQ.1)CZ(IROW,ICOL)=CZ(IROW,ICOL)
     $        +FLAG*(CTEMP-CSPOT)*SM(IML)
                        IF(IFS.EQ.1.AND.IV.EQ.1)CV(IROW)=CV(IROW)+
     $FLAG*SM(IML)*CETEMP
C
C ZBJ : HAS JUNCTION IN THIS SOURCE TRIANGLE,
C      NO JUNCTION IN THIS MATCH TRIANGLE
C
      IF(JSF.NE.0.AND.IV.LE.1) THEN
        CBJEMP=CAJ(1)*T1+CAJ(2)*T2+CAJ(3)*T3
                    IF(NFIELD.EQ.1)CZ(IROW,JSCOL)=CZ(IROW,JSCOL)
     $        +FLAG*(CBJEMP-CSJPOT)*SM(IML)*ANGS
      ENDIF
C
```

```
C VJ: FORCE AT JUNCTION POINT
C
      IF(JMF.NE.0.AND.IV.EQ.1)THEN
                         EDOTT=EX*VMJUN(1)+EY*VMJUN(2)+EZ*VMJUN(3)
                         CJETEMP=EDOTT*CEXP(CARG)
                          IF(IFS.EQ.1.AND.IV.EQ.1)CV(JMROW)=CV(JMROW)-
     $CJETEMP*ANGM
      ENDIF
50                      CONTINUE
                      ENDIF
                    ENDIF
 100              CONTINUE
 450            CONTINUE
              ENDIF
 460        CONTINUE
C
C ZJJ : HAS JUNCTION IN THIS SOURCE TRIANGLE,
C       HAS JUNCTION IN THIS MATCH TRIANGLE
C
      IF(JSF.NE.0.AND.JMF.NE.0)THEN
C VECTOR POTENTIAL DOT WITH TESTING VECTOR
      CJJEMP=CAJ(1)*VMJUN(1)+CAJ(2)*VMJUN(2)+CAJ(3)*VMJUN(3)
C SET + TO VECTOR POTENTIAL AND - TO SCALAR POTENTIAL
      IF(NFIELD.EQ.1)CZ(JMROW,JSCOL)=CZ(JMROW,JSCOL)
     $ +(CJJEMP-CSJPOT)*ANGM*ANGS
      ENDIF
C
 499      CONTINUE
        ENDIF
 999  CONTINUE
      RETURN
      END
```

A.44 ZWB

```
C======================================================================
      SUBROUTINE ZWB(DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,NEDGES,
     $        NFACES,NUNKNT,CZ,INDSUM,NWNOD,NWSEG,WNODE,NSEGC,WSEGH,
     $        MXWMLT,MULTW,INSEG,WIRSUM,NUNKNB,
     &        NJCT,MNJUN,MNJFACE,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C------------------------------------------------------------------
C THIS ROUTINE FILL OUT THE MATRIX ELEMENTS OF ZWB WHICH IS SOURCE POINT
C  ON THE BODY AND MATCH POINT ON THE WIRE
```

```
C--------------------------------------------------------------------------
      REAL ANG(MNJUN,MNJFACE),XS(3),YS(3),ZS(3),VSJUN(3)
     &      ,DATNOD(3,NNODES),TMAT(3,3),RK(3,3),RMK(3),SM(3)
     &      ,LAMBDA,K,MU,IMP
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &       NWJUN(MNJUN),NS(3),IGNDP(3)
     &      ,NCONN(3,NEDGES),NBOUND(3,NFACES),IEDGF(MULT1,NEDGES),
     $ IM(3),IS(3),MULTW(NWNOD),INSEG(MXWMLT+1,NWNOD),WIRSUM(NWNOD)
      DIMENSION WNODE(3,NWNOD),NSEGC(2,NWSEG),WSEGH(3,NWSEG),T(3)
     &        ,INDSUM(NEDGES),AL(3),DL(3,3),H(3),
     &        DN(3,3),DLN(3),SN(3),DM(3,3),DMC(3),DLM(3)
      COMPLEX CWJEMP,CZ(NUNKNT,NUNKNT),HTHETA,HPHI,ETHETA,EPHI,
     $ EX,EY,EZ,EDOTT,CVPB,CSPB,C,CI(3),CAX,CAY,CAZ,CSPOT,CFLAG,CARG,
     $ CTEMP,CETEMP,CP(3),CPP,CMM,CAJ(3),CAJT(3),CA(3),CSJPOT
C
C VARIABLES ASSOCIATED WITH IMAGE PATCH
     $ ,CII(3),CPPI,CMMI,CAI(3),CAJTI(3),CAA(3,3),CX,CJ
C
      LOGICAL LOWS,LOWM,PLUS
C
      COMMON/PARA/DL,DET,H,AL
      COMMON/GPLANE/NGNDP,IGNDP
C
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/PARAM/THETA,PHI,NFIELD
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
C THE FOLLOWING LINE IS A STATEMENT FUNCTION.
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
C SET CONSTANTS.
      CVPB=CMPLX(0.,IMP/(4.*PI))
      CSPB=CMPLX(0.,.5/(PI*OMEGA*EPSLON))
C LOOP OVER THE FACE NUMBERS OF THE SOURCE TRIANGLES.
      DO 999 IFS=1,NFACES
      IIS=1
        IF(IFS.EQ.1.OR.NFIELD.LE.1)THEN
C OBTAIN THE EDGES OF THE SOURCE TRIANGLE.
C OBTAIN THE COORDINATES OF THE SOURCE TRIANGLE'S VERTICIES.
C STORE IN RK(J,I) I=1,2,3 K*THE X,Y,Z COORDINATES OF THE JTH VERTEX
C OF THE SOURCE TRIANGLE.
C
C OBTAIN THE EDGES OF THE SOURCE TRIANGLE
          CALL FACEDG(NFACES,NBOUND,IFS,IS)
C OBTAIN THE VERTICES OF THE SOURCE TRIANGLE
          CALL FACVTX(NCONN,NEDGES,IS,NS)
```

```
C OBTAIN THE COORDINATES OF THE SOURCE TRIANGLE'S VERTICIES
          CALL VTXCRD(DATNOD,NNODES,NS,DN)
      DO 2 I=1,3
      DO 2 J=1,3
2      RK(I,J)=K*DN(I,J)
           DO 88 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      DO 77 J=1,3
77      DLN(J)=DN(IM1,J)-DN(IP1,J)
88       SN(I)=SIZE(DLN(1),DLN(2),DLN(3))
C
C IF NJCT=0, NO JUNCTION CASE
C IF NJCT=1, CHECK IF ANY JUNCTION IN THIS SOURCE TRIANGLE
C IF JSF=0, NO JUNCTION IN THIS SOURCE TRIANGLE
C IF JSF=N, N=1,2,3, FIND OUT ASSOCIATED PARAMETERS
C
      IF(NJCT.EQ.1) THEN
C TO GET PARAMATERS ASSOCIATE WITH THIS JUNCTION
      CALL JUNPAR(JSF,DN,NS,IFS,ANGS,VSJUN,JSCOL,
     &      WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C ANGS IS THE ANGULAR DISTRIBUTION COEFFICIENCY OF MATCH TRIANGLE
C SN(JMF) IS THE LENGTH OF OPPOSITE EDGE
      IF(JSF.NE.0)      ANGS=ANGS/SN(JSF)
      ELSE
      JSF=0
      ENDIF
C
* LOOP OVER THE MATCH SEGMENTS.
C
          DO 499 NM=1,NWSEG
C
* OBTAIN COORDINATES OF TEST VECTOR AND MATCH SEGMENT CENTROID TIMES K.
C
            NMF=NSEGC(1,NM)
            NMT=NSEGC(2,NM)
            DO 5 J=1,3
              T(J)=.5*(WNODE(J,NMT)-WNODE(J,NMF))
             RMK(J)=K*WSEGH(J,NM)
5           CONTINUE
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
C CAA(I)= INTEGRAL OF ( XSI(I)*(EXP(-JKR)-XSING)/R D (XSI(I))
C D(XSI(I+1))) IF XSING=1 THEN +1/(2*AREA)*INTEGRAL OF XSI(I)/R
```

```
C D(S')  XSI(I),I=1,3 DENOTE ZETA, XSI AND ETA, XSING=0 OR 1
C DL(I,J) IS THE VECTOR FROM THE I+1TH VERTEX TO THE ITH VERTEX
C AL(I) IS THE LENGTH OF THE DL(I,J)
C
           CALL POTBOD(JSF,RK,RMK,C,CAA,CAJT,0)
      IF(JSF.NE.0) THEN
      ISL=JSF
C SET (+) TO CA (-) TO CAJT (+) TO CSJPOT
      FLAG=AL(JSF)
                CFLAG=CVPB*FLAG
C
C CAA(J),J=1,3 ARE THE X,Y,Z COMPONENTS OF THE VECTOR PONTETIAL
C DUE TO THE TRIANGULAR BASIS FUNCTICN
C CAA=(SGN)*MU*AL(I)/4*PI*(CI(I+1)*DL(I-1,J)-CI(I-1)*DL(I+1,J))
C CAJT(J) IS THE VECTOR POTENTIAL DUE TO THE JUNCTION PART OF
C THE JUNCTION BASIS FUNCTION
C CAJ(J) IS THE VECTOR POTENTIAL DUE TO THE JUNCTION
C BASIS FUNCTION
      DO 29 J=1,3
29      CAJ(J)=(CFLAG*CAA(JSF,J)-CVPB*CAJT(J))
C COMPUTE CSJPOT THE SCALAR POTENTIAL ASSOCIATED WITH JUNCTION
                CSJPOT=CSPB*C*AL(JSF)
      ENDIF
      IV=0
            DO 460 ISL=1,3
              ISS=IS(ISL)
              MULTS=NCONN(3,ISS)
              IF(MULTS.NE.0)THEN
                IF(ISL.EQ.1)THEN
                  FLAG=AL(1)
                  IF(NCONN(1,IS(1)).EQ.NS(3))FLAG=-FLAG
                ELSEIF(ISL.EQ.2)THEN
                  FLAG=AL(2)
                  IF(NCONN(1,IS(2)).EQ.NS(1))FLAG=-FLAG
                ELSE
                  FLAG=AL(3)
                  IF(NCONN(1,IS(3)).EQ.NS(2))FLAG=-FLAG
                ENDIF
                CFLAG=CVPB*FLAG
      IP1=MOD(ISL,3)+1
      IM1=MOD(ISL+1,3)+1
C
C CA(J),J=1,3 ARE THE X,Y,Z COMPONENTS OF THE VECTOR PONTETIAL
C CA=(SGN)*MU*AL(I)/4*PI*(CI(I+1)*DL(I-1,J)-CI(I-1)*DL(I+1,J))
C
```

```
      DO 9 J=1,3
9      CA(J)=CFLAG*CAA(ISL,J)
C
C COMPUTE CSPOT THE SCALAR POTENTIAL.
                CSPOT=CSPB*FLAG*C
C FOR AN EDGE WITH MULTIPLICITY MULT, THE LOWEST NUMBERED FACE
C CONTRIBUTES TO MULT BASIS FUNCTIONS ASSOCIATED WITH THAT EDGE,
C WHILE EACH REMAINING FACE CONTRIBUTES TO ONE BASIS FUNCTION ASSOCIATED
C WITH THAT EDGE.
                CALL EDGMUL(IEDGF,MULT1,NEDGES,MULTS,ISS,IFS,JS1,JS2)
                                   INDS=INDSUM(ISS)
                DO 450 JS=JS1,JS2
                  IV=IV+1
                  ICOL=INDS+JS
C COMPUTE QUANTITIES ASSOCIATED WITH THE INCIDENT FIELD.
                  CTEMP=(CA(1)*T(1)+CA(2)*T(2)+CA(3)*T(3))
C
* LOOP OVER THE NODES ATTACHED TO THE MATCH SEGMENT.
C
                  DO 250 JMN=1,2
                    NODEM=NSEGC(JMN,NM)
                    MULTM=MULTW(NODEM)
                    IF(MULTM.GT.0)THEN
C
* COMPUTE ROW INDEX FOR SOURCE SEGMENT.
C
                      INDR=WIRSUM(NODEM)
C
* DETERMINE WHETHER SEGMENT NM IS THE LOWEST SEGMENT ATTACHED
* TO SEGMENT NM AT NODE NODEM.LOOP OVER THE NUMBER OF SEGMENTS ATTACHED
* TO SEGMENT NM AT NODE NODEM.
C
      IF(NODEM.EQ.NWJUN(MNJUN)) THEN
      JM1=1
      JM2=1
      LOWM=.FALSE.
      ELSE
                      CALL NODMUL(INSEG,MXWMLT,NWNOD,NODEM,MULTM,NM,
     >                          JM1,JM2,LOWM)
      ENDIF
                      DO 200 JM=JM1,JM2
C
* DETERMINE WHETHER SEGMENT IS A PLUS OR MINUS SEGMENT
C
                        IF(NODEM.EQ.NSEGC(2,NM))THEN
```

```
                    SGN1=1.
                  ELSE
                    SGN1=-1.
                  ENDIF
                  IF(LOWM)THEN
C
* CASE: SEGMENT NM IS THE LOWEST NUMBERED SEGMENT ATTACHED TO NODE
* NODEM. DIRECTION OF THE BASIS FUNCTION IS DETERMINED BY THE ATTACHED
* SEGMENT. OBTAIN ATTACHED SEGMENT.
C
                    NSEGAM=INSEG(JM+1,NODEM)
                    IF(NSEGC(2,NM).EQ.NSEGC(1,NSEGAM).OR.
     >                 NSEGC(1,NM).EQ.NSEGC(2,NSEGAM))THEN
                      SGN=1.
                    ELSE
                      SGN=-1.
                    ENDIF
                  ELSE
                    SGN=1.
                  ENDIF
      IF(NODEM.EQ.NWJUN(MNJUN))THEN
                  IF(NODEM.EQ.NSEGC(2,NM))THEN
      SGN=-1.
      SGN1=1.
      ELSE
      SGN=1.
      SGN1=-1.
      ENDIF
      ENDIF
                 IROW=INDR+JM
                    IF(NFIELD.EQ.1)CZ(IROW,ICOL)=CZ(IROW,ICOL)
     $        +SGN*(CTEMP-CSPOT*SGN1)
C
C ZWJ: HAS JUNCTION IN THIS SOURCE TRIANGLE
C
      IF(JSF.NE.0.AND.IV.LE.1)THEN
C VECTOR POTENTIAL DOT WITH TESTING VECTOR
      CWJEMP=CAJ(1)*T(1)+CAJ(2)*T(2)+CAJ(3)*T(3)
                    IF(NFIELD.EQ.1)CZ(IROW,JSCOL)=CZ(IROW,JSCOL)
     $        +SGN*(CWJEMP-CSJPOT*SGN1)*ANGS
      ENDIF
C
 200                CONTINUE
                  ENDIF
 250            CONTINUE
```

```
 450           CONTINUE
             ENDIF
 460         CONTINUE
499       CONTINUE
        ENDIF
 999  CONTINUE
      RETURN
      END
```

A.45 PATTEN

```
C=====================================================================
      SUBROUTINE PATTEN(DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,WIRSUM,
     $NEDGES,NFACES,NUNKNT,CJ,INDSUM,IPAT,NJCT,MNJUN,MNJFACE,NWNOD,
     $ANG,NJFACE,MIFACE,NWJUN,NBJUN,MXWMLT,NWSEG,NUNKNB,WNODE,MULTW,
     $NSEGC,WSEGH,RAD,INSEG)
C---------------------------------------------------------------------
C INPUT:
C  DATNOD(I,J) I=1,2,3 ARE THE X,Y,Z COMPONENTS OF THE JTH VERTEX.
C  THE JTH EDGE RUNS FROM NCONN(1,J) TO NCONN(2,J). NCONN(3,J) IS THE
C  MULTIPLICITY OF THE JTH EDGE(I.E. THE NUMBER OF UNKNOWNS ASSOCIATED
C  WITH THAT EDGE.)
C  NBOUND(I,J) I=1,2,3 ARE THE 3 EDGES OF THE JTH FACE.
C  NNODES IS THE NUMBER OF NODES ON THE BODY.
C  NEDGES IS THE NUMBER OF EDGES.
C  NFACES IS THE NUMBER OF BODY FACES.
C  NUNKNT IS THE TOTAL NUMBER OF UNKNOWNS.
C  CJ IS A COMPLEX ARRAY CONTAINING THE CURRRENT AMPLITUDES
C  ALSO THE COMMON FIELDS /MEDIUM,FINDIF,WAVE/ ARE COMPUTED IN INDATA
C  AND IN SOLTN.
C
C OUTPUT:
C   ES,HS ARE ARRAYS CONTAINING THE FIELD VALUES
C   AT THE OBSERVATION POINTS.
C
      REAL ANG(MNJUN,MNJFACE),VSJUN(3),H(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &      NWJUN(MNJUN),WIRSUM(NWNOD)
C
      COMPLEX CV(100)
      DIMENSION WNODE(3,NWNOD),MULTW(NWNOD),NSEGC(2,NWSEG),
     >          WSEGH(3,NWSEG),RAD(NWSEG),INSEG(MXWMLT+1,NWNOD)
C
```

```
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IEDGF(MULT1,NEDGES),
     $IS(3),INDSUM(NEDGES),NS(3)
      DIMENSION DATNOD(3,NNODES),TMAT(3,3),RK(3,3),RMK(3),RFLD(3,6),
     $DK(3)
      COMPLEX ETH(100,100),EPH(100,100),HSQR,RCS(10,10),SIGMA
     $,ETHSQR(10,10),EPHSQR(10,10)
      COMPLEX ES(3),HS(3),CJ(NUNKNT),CH,CAXJ,CAYJ,CAZJ,CA(3),CI(3),
     $CVPB,CSPB,C,CVEC(3),CAX,CAY,CAZ,CSPOT,CFLAG,
     $CTEMP,CSPOTJ,CP(3)
      COMPLEX HTHETA,HPHI,ETHETA,EPHI
      REAL LAMBDA,K,MU,IMP
      REAL MAGH(3,3),LMINK,LMAXK,HHAT(3,3),DN(3,3)
      REAL L(3,3),LHAT(3,3),NHAT(3),MAGL(3)
      COMMON/PARA/L,MAGL,AREAX2,H
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/FINDIF/NNFLD,DX,DY,DZ
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/PAT/PHI1,PHI2,NPHI,THETA1,THETA2,NTHETA
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
C SET CONSTANTS.
      CVPB=CMPLX(0.,IMP/(4.*PI))
      WRITE(10,101)
 101  FORMAT(X,/25X,'FAR FIELD PATTERN',/)
      WRITE(10,102)
102   FORMAT(X,'ITHETA',2X,'THETA',2X,'IPHI',2X,'PHI',3X,
     &'ETH(ITHETA,IPHI)',5X,'EPH(ITHETA,IPHI)',/)
C LOOP OVER FIELD OBSERVATION POINTS.
        IF(NPHI.EQ.1)THEN
        DPHI=0
        ELSE
        DPHI=(PHI2-PHI1)/FLOAT(NPHI-1)
        ENDIF
        IF(NTHETA.EQ.1)THEN
        DTHETA=0
        ELSE
        DTHETA=(THETA2-THETA1)/FLOAT(NTHETA-1)
        ENDIF
        DO 999 ITHETA=1,NTHETA
         THETA=THETA1+(ITHETA-1)*DTHETA
         DO 998 IPHI=1,NPHI
          PHI=PHI1+(IPHI-1)*DPHI
            RMK(1)=SIND(THETA)*COSD(PHI)
            RMK(2)=SIND(THETA)*SIND(PHI)
            RMK(3)=COSD(THETA)
            ETH(ITHETA,IPHI)=(0.,0.)
```

```
         EPH(ITHETA,IPHI)=(0.,0.)
      CALL BPATTN(IPAT,DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,NEDGES,
     $         NFACES,NUNKNT,CJ,CV,INDSUM,NJCT,MNJUN,MNJFACE,NWNOD,WIRSUM,
     $         ANG,NJFACE,MIFACE,NWJUN,NBJUN,RMK,ETH,EPH,ITHETA,IPHI,THETA,
     $         PHI)
C-----------------------------------------------------------------------
        IF(NJCT.GE.0)THEN
      CALL WPATTN(IPAT,MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,MULTW,
     $NSEGC,WSEGH,RAD,INSEG,CJ,CV,WIRSUM,NWJUN,MNJUN,RMK,ETH,EPH,ITHETA,
     $        IPHI,THETA,PHI)
        ENDIF
C-----------------------------------------------------------------------
C COMPUTE RADAR CROSS SECTION
C
C        ETHSQR(ITHETA,IPHI)=ETH(ITHETA,IPHI)*CONJG(ETH(ITHETA,IPHI))
C        EPHSQR(ITHETA,IPHI)=EPH(ITHETA,IPHI)*CONJG(EPH(ITHETA,IPHI))
C        SIGMA=4.*PI*(ETHSQR(ITHETA,IPHI)+EPHSQR(ITHETA,IPHI))/
C     1        (IMP*IMP)
C        HSQR=HTHETA*CONJG(HTHETA)+HPHI*CONJG(HPHI)
C        RCS(ITHETA,IPHI)=SIGMA/HSQR
C
C      WRITE(15,*)RCS(ITHETA,IPHI)
C 1001    FORMAT(1X,2I6,2F10.5)
 998  CONTINUE
 999  CONTINUE
      RETURN
      END
```

A.46 BPATTN

```
C=======================================================================
      SUBROUTINE BPATTN(IPAT,DATNOD,NCONN,NBOUND,IEDGF,MULT1,NNODES,
     $NEDGES,NFACES,NUNKNT,CJ,CV,INDSUM,NJCT,MNJUN,MNJFACE,NWNOD,WIRSUM,
     $         ANG,NJFACE,MIFACE,NWJUN,NBJUN,RMK,ETH,EPH,ITHETA,IPHI,THETA,
     $         PHI)
C-----------------------------------------------------------------------
      COMPLEX ETH(100,100),EPH(100,100),CAXJ,CAYJ,CAZJ
      REAL ANG(MNJUN,MNJFACE),VMJUN(3),VSJUN(3),H(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &         NWJUN(MNJUN),WIRSUM(NWNOD)
C
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),IEDGF(MULT1,NEDGES),
     $         IM(3),IS(3),NS(3),NM(3),IGNDP(3)
```

```
      DIMENSION INDSUM(NEDGES),DN(3,3),DM(3,3),DMC(3),DLM(3),AL(3)
     $      ,SN(3),DLN(3),DATNOD(3,NNODES),TMAT(3,3),RK(3,3),RMK(3),
     $      SM(3),DL(3,3)
      COMPLEX CJ(NUNKNT),CV(NUNKNT),CVPB,C,CI(3),CA(3),CFLAG,
     $CAJ(3),CAJT(3)
C
C VARIABLES ASSOCIATED WITH IMAGE PATCH
     $,CAA(3,3)
C
      REAL LAMBDA,K,MU,IMP
      COMMON/PARA/DL,DET,H,AL
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/GPLANE/NGNDP,IGNDP
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      CVPB=CMPLX(0.,IMP/(4.*PI))
C
      DO 999 IFS=1,NFACES
      IIS=1
C OBTAIN THE EDGES OF THE SOURCE TRIANGLE
          CALL FACEDG(NFACES,NBOUND,IFS,IS)
C OBTAIN THE VERTICES OF THE SOURCE TRIANGLE
          CALL FACVTX(NCONN,NEDGES,IS,NS)
C OBTAIN THE COORDINATES OF THE SOURCE TRIANGLE'S VERTICIES
          CALL VTXCRD(DATNOD,NNODES,NS,DN)
      DO 2 I=1,3
      DO 2 J=1,3
2     RK(I,J)=K*DN(I,J)
      DO 88 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      DO 77 J=1,3
77    DLN(J)=DN(IM1,J)-DN(IP1,J)
88    SN(I)=SIZE(DLN(1),DLN(2),DLN(3))
C IF NJCT=0, NO JUNCTION CASE
C IF NJCT=1, CHECK IF ANY JUNCTION IN THIS SOURCE TRIANGLE
C IF JSF=0, NO JUNCTION IN THIS SOURCE TRIANGLE
C IF JSF=N, N=1,2,3, FIND OUT ASSOCIATED PARAMETERS
C
      IF(NJCT.EQ.1) THEN
C TO FIND PARAMATERS ASSOCIATE WITH THIS JUNCTION
      CALL JUNPAR(JSF,DN,NS,IFS,ANGS,VSJUN,JSCOL,
     &      WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C ANGS IS THE ANGULAR DISTRIBUTION COEFFICIENCY OF SOURCE TRIANGLE
```

```
C SN(JMF) IS THE LENGTH OF OPPOSITE EDGE
      IF(JSF.NE.0)      ANGS=ANGS/SN(JSF)
      ELSE
      JSF=0
      ENDIF
C
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
C CAA(I)= INTEGRAL OF ( XSI(I)*(EXP(-JKR)-XSING)/R D (XSI(I))
C D(XSI(I+1))) IF XSING=1 THEN +1/(2*AREA)*INTEGRAL OF XSI(I)/R
C D(S')  XSI(I),I=1,3 DENOTE ZETA, XSI AND ETA, XSING=0 OR 1
C DL(I,J) IS THE VECTOR FROM THE I+1TH VERTEX TO THE ITH VERTEX
C AL(I) IS THE LENGTH OF THE DL(I,J)
C
           CALL POTBOD(JSF,RK,RMK,C,CAA,CAJT,IPAT)
      IF(JSF.NE.0) THEN
      ISL=JSF
C SET (+) TO CA (-) TO CAJT (+) TO CSJPOT
      FLAG=AL(JSF)
               CFLAG=CVPB*FLAG
C
C CAA(J),J=1,3 ARE THE X,Y,Z COMPONENTS OF THE VECTOR PONTETIAL
C DUE TO THE TRIANGULAR BASIS FUNCTION
C CAA=(SGN)*MU*AL(I)/4*PI*(CI(I+1)*DL(I-1,J)-CI(I-1)*DL(I+1,J))
C CAJT(J) IS THE VECTOR POTENTIAL DUE TO THE JUNCTION PART OF
C THE JUNCTION BASIS FUNCTION
C CAJ(J) IS THE VECTOR POTENTIAL DUE TO THE JUNCTION
C BASIS FUNCTION
C SET (+) TO CA (-) TO CAJT (+) TO CSJPOT
C
      DO 29 J=1,3
29        CAJ(J)=(CFLAG*CAA(JSF,J)-CVPB*CAJT(J))
C
      ENDIF
            IV=0
            DO 460 ISL=1,3
              ISS=IS(ISL)
              MULTS=NCONN(3,ISS)
              IF(MULTS.NE.0)THEN
                IF(ISL.EQ.1)THEN
                  FLAG=AL(1)
                  IF(NCONN(1,IS(1)).EQ.NS(3))FLAG=-FLAG
                ELSEIF(ISL.EQ.2)THEN
                  FLAG=AL(2)
```

```
                  IF(NCONN(1,IS(2)).EQ.NS(1))FLAG=-FLAG
                ELSE
                  FLAG=AL(3)
                  IF(NCONN(1,IS(3)).EQ.NS(2))FLAG=-FLAG
                ENDIF
                CFLAG=CVPB*FLAG
      IP1=MOD(ISL,3)+1
      IM1=MOD(IP1,3)+1
C
C CA(J),J=1,3 ARE THE X,Y,Z COMPONENTS OF THE VECTOR PONTETIAL
C CA=(SGN)*MU*AL(I)/4*PI*(CI(I+1)*DL(I-1,J)-CI(I-1)*DL(I+1,J))
C
      DO 9 J=1,3
9      CA(J)=CFLAG*CAA(ISL,J)
C
C FOR AN EDGE WITH MULTIPLICITY MULT, THE LOWEST NUMBERED FACE
C CONTRIBUTES TO MULT BASIS FUNCTIONS ASSOCIATED WITH THAT EDGE,
C WHILE EACH REMAINING FACE CONTRIBUTES TO ONE BASIS FUNCTION ASSOCIATED
C WITH THAT EDGE.
               IF(MULTS.NE.0)THEN
                 CALL EDGMUL(IEDGF,MULT1,NEDGES,MULTS,ISS,IFS,JS1,JS2)
                                    INDS=INDSUM(ISS)
                 DO 450 JS=JS1,JS2
                   IV=IV+1
                   ICOL=INDS+JS
C
                     CAXJ=CA(1)*CJ(ICOL)/K
                     CAYJ=CA(2)*CJ(ICOL)/K
                     CAZJ=CA(3)*CJ(ICOL)/K
                     CAZJ=CA(3)*CJ(ICOL)/K
C
C IT HAS JUNCTION IN THIS SOURCE TRIANGLE,
      IF(JSF.NE.0.AND.IV.LE.1) THEN
                     CAXJ=CAXJ+CAJ(1)*CJ(JSCOL)/K
                     CAYJ=CAYJ+CAJ(2)*CJ(JSCOL)/K
                     CAZJ=CAZJ+CAJ(3)*CJ(JSCOL)/K
        ENDIF
                     ETH(ITHETA,IPHI)=ETH(ITHETA,IPHI)
     1                                -CAXJ*COSD(THETA)*COSD(PHI)
     2                                -CAYJ*COSD(THETA)*SIND(PHI)
     3                                +CAZJ*SIND(THETA)
                     EPH(ITHETA,IPHI)=EPH(ITHETA,IPHI)
     1                                +CAXJ*SIND(PHI)
     2                                -CAYJ*COSD(PHI)
C
```

```
450            CONTINUE
             ENDIF
             ENDIF
460        CONTINUE
999   CONTINUE
        IF(NJCT.LT.0)THEN
      WRITE(10,1000)ITHETA,THETA,IPHI,PHI,ETH(ITHETA,IPHI),EPH(ITHETA,
     1IPHI)
1000  FORMAT(I5,F8.2,I5,F8.2,4(1PE10.2))
        ENDIF
      RETURN
      END
```

A.47 WPATTN

```
C=====================================================================
      SUBROUTINE WPATTN(IPAT,MXWMLT,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,
     $MULTW,NSEGC,WSEGH,RAD,INSEG,CJ,CV,WIRSUM,NWJUN,MNJUN,RM,ETH,EPH,
     $ITHETA,IPHI,THETA,PHI)
C---------------------------------------------------------------------
      COMPLEX ETH(100,100),EPH(100,100),CAXJ,CAYJ,CAZJ
      DIMENSION WNODE(3,NWNOD),MULTW(NWNOD),NSEGC(2,NWSEG),
     >          WSEGH(3,NWSEG),RAD(NWSEG),INSEG(MXWMLT+1,NWNOD),
     >          RMK(3),SH(3),RSK(3),T(3),RM(3)
      COMPLEX CJ(NUNKNT),CV(NUNKNT),
     >        CSPW,HTHETA,HPHI,ETHETA,EPHI,EX,EY,EZ,ANS(3),
     >        SPOT,VAP(3),VAM(3),SSPOT,VA(3)
     >        ,CKRED,CKTOT,CKSELF,CANS
      INTEGER WIRSUM(NWNOD),NWJUN(MNJUN)
      REAL LAMBDA,K,MU,IMP
      EXTERNAL CKRED,CKTOT,CKSELF
      LOGICAL LOWS,LOWM,PLUS
      SAVE /WAVE/,/PARAM/,/INC/,/MEDIUM/,/WKERNL/,/WIRE/,/WKER/
      COMMON/POT/NM,NS,DEL,DELS,DELH,DELRH,RVPW,CSPW,RADMKS
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/INC/HTHETA,HPHI,ETHETA,EPHI
      COMMON/WKERNL/RSK,SH,RMK,RADSK,RADSKS
      COMMON/WKER/DPAR,RHO,RHOPR,RHOPRS,RHOMRS
      COMMON/WIRE/IQUADW
      COMMON/WIRSLF/IQWS
C
* SET CONSTANTS.
```

```
C
      IQUAD=IQUADW
      IQUAWS=IQWS
      PI4=4.*PI
      RVPW=MU/PI4
      CSPW=CMPLX(0.,1./(OMEGA*EPSLON*PI4))
        DO 5 J=1,3
5       RMK(J)=RM(J)
C
* LOOP OVER THE SOURCE SEGMENTS.
C
      DO 1000 NS=1,NWSEG
        RADSK=K*RAD(NS)
        RADSKS=RADSK*RADSK
        DELRH=15.*RADSK
C
* OBTAIN K* THE COORDINATES OF THE SOURCE SEGMENT CENTROID
C
          NSF=NSEGC(1,NS)
          NST=NSEGC(2,NS)
          DO 2 J=1,3
            RSK(J)=K*WSEGH(J,NS)
            SH(J)=K*(WNODE(J,NST)-WNODE(J,NSF))
 2        CONTINUE
          DEL=SQRT(SH(1)*SH(1)+SH(2)*SH(2)+SH(3)*SH(3))
          DELS=DEL*DEL
          DELH=.5*DEL
          DO 4 J=1,3
            SH(J)=SH(J)/DEL
 4        CONTINUE
C
* LOOP OVER THE MATCH SEGMENTS.
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
      CALL POTWIR(SSPOT,VAP,VAM,IPAT)
            Iv=0
C
* LOOP OVER NODES ATTACHED TO THE SOURCE SEGMENT.
C
            DO 400 JNS=1,2
              NODES=NSEGC(JNS,NS)
              MULTS=MULTW(NODES)
              IF(MULTS.GT.0)THEN
C
```

```
* COMPUTE COLUMN INDEX FOR SOURCE SEGMENT.
C
               INDC=WIRSUM(NODES)
C
*  DETERMINE WHETHER SEGMENT NS IS THE LOWEST SEGMENT ATTACHED TO NODE
*  NODES.LOOP OVER THE NUMBER OF SEGMENTS ATTACHED TO NS AT NODE NODES.
C
               CALL NODMUL(INSEG,MXWMLT,NWNOD,NODES,MULTS,NS,JS1,JS2,
     >                  LOWS)
      IF(LOWS.AND.NODES.EQ.NWJUN(MNJUN)) THEN
      JS1=1
      JS2=1
      LOWS=.FALSE.
      ENDIF
               DO 300 J=JS1,JS2
                 ICOL=INDC+J
                 IV=IV+1
                 IF(NODES.EQ.NSEGC(2,NS))THEN
                   PLUS=.TRUE.
                 ELSE
                   PLUS=.FALSE.
                 ENDIF
                 IF(LOWS)THEN
C
* OBTAIN THE ATTACHED SEGMENT.
C
                   NSEGAS=INSEG(J+1,NODES)
C
* SGN=+1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE SAME DIRECTION,
* SGN=-1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE OPPOSITE DIRECTION
C
                   IF(NSEGC(2,NS).EQ.NSEGC(1,NSEGAS).OR.
     >                NSEGC(1,NS).EQ.NSEGC(2,NSEGAS))THEN
                     SGN=1.
                   ELSE
                     SGN=-1.
                   ENDIF
                 ELSE
                   SGN=1.
                 ENDIF
C
C
* COMPUTE APPROPRIATE VECTOR AND SCALAR POTENTIALS.
C
                 IF(PLUS)THEN
```

```
C
C FOR PLUS SOURCE SEGMENT SET SIGN= (-1) TO VECTOR AND SCALAR POTENTIALS
C
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=-1.
                   DO 30 JJ=1,3
                     VA(JJ)=VAP(JJ)*SGN
 30                CONTINUE
                 ELSE
C
C FOR MINUS SOURCE SEGMENT SET SIGN= (+1) TO VECTOR POTENTIAL AND
C (-1) TO SCALAR POTENTIALS
C
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=1.
                   DO 40 JJ=1,3
                     VA(JJ)=VAM(JJ)*SGN
 40                CONTINUE
                 ENDIF
C
                   CAXJ=VA(1)*CJ(ICOL)/K*CMPLX(0.,OMEGA)
                   CAYJ=VA(2)*CJ(ICOL)/K*CMPLX(0.,OMEGA)
                   CAZJ=VA(3)*CJ(ICOL)/K*CMPLX(0.,OMEGA)
                   ETH(ITHETA,IPHI)=ETH(ITHETA,IPHI)
     1                                 -CAXJ*COSD(THETA)*COSD(PHI)
     2                                 -CAYJ*COSD(THETA)*SIND(PHI)
     3                                 +CAZJ*SIND(THETA)
                   EPH(ITHETA,IPHI)=EPH(ITHETA,IPHI)
     1                                 +CAXJ*SIND(PHI)
     2                                 -CAYJ*COSD(PHI)
 300             CONTINUE
               ENDIF
 400         CONTINUE
 1000 CONTINUE
      WRITE(10,1100)ITHETA,THETA,IPHI,PHI,ETH(ITHETA,IPHI),EPH(ITHETA,
     1IPHI)
 1100 FORMAT(I5,F8.2,I5,F8.2,4(1PE10.2))
C 1100 FORMAT(I5,F10.3,I5,F10.3,4(1PE15.5))
      RETURN
      END
```

A.48 CHARGE

```
C=====================================================================
      SUBROUTINE CHARGE(NJCT,CI,DATNOD,NCONN,NBOUND,NNODES,NEDGES,
```

```
     $ NFACES,NUNKNT,NWNOD,NWSEG,NUNKNB,WNODE,WIRSUM,NSEGC,MULTW,
     $ MNJUN,MNJFACE,ANG,NJFACE,MIFACE,NWJUN,NBJUN,INDSUM,
     $ IEDGF,MULT1,INSEG,MXWMLT)
C-----------------------------------------------------------------------
C
C THIS SUBROUTINE COMPUTES THE CHARGE DISTRIBUTION ON THE
C BODY.THE CHARGE DENSITY IS COMPUTED AT THE CENTROID OF
C EACH TRIANGLE.
C
      IMPLICIT COMPLEX (C)
      COMPLEX CI(NUNKNT)
      REAL ANG(MNJUN,MNJFACE),VSJUN(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &      NWJUN(MNJUN),INSEG(MXWMLT+1,NWNOD)
      DIMENSION DATNOD(3,NNODES)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),INDSUM(NEDGES),
     $WIRSUM(NWNOD),NSEGC(2,NWSEG),MULTW(NWNOD)
      REAL WNODE(3,NWNOD)
C
C COMPUTE CHARGE DENSITY ON THE BODIES
C
      CALL QBODY(NJCT,CI,DATNOD,NCONN,NBOUND,NNODES,NEDGES,
     $NFACES,NUNKNT,NUNKNB,INDSUM,
     $ WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN,
     $IEDGF,MULT1)
C
C COMPUTE CHARGE DENSITY ON THE WIRES
C
      IF(NJCT.GE.0)THEN
        CALL QWIRE(CI,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,WIRSUM,NSEGC,
     $  MULTW,MNJUN,NWJUN,INSEG,MXWMLT)
      ENDIF
C
      RETURN
      END
```

A.49 QBODY

```
C=======================================================================
      SUBROUTINE QBODY(NJCT,CI,DATNOD,NCONN,NBOUND,NNODES,NEDGES,
     $NFACES,NUNKNT,NUNKNB,INDSUM,
     $ WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN,
     $IEDGF,MULT1)
```

```
C------------------------------------------------------------------------
C
C THIS SUBROUTINE COMPUTES THE CHARGE DISTRIBUTION ON THE
C BODY.THE CHARGE DENSITY IS COMPUTED AT THE CENTROID OF
C EACH TRIANGLE.
C
      IMPLICIT COMPLEX (C)
      COMPLEX CI(NUNKNT),CS(3)
C
      REAL ANG(MNJUN,MNJFACE),VSJUN(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &       NWJUN(MNJUN),WIRSUM(NWNOD)
C
      DIMENSION DATNOD(3,NNODES),DN(3,3),IS(3),NS(3),DLM(3),SM(3)
      INTEGER NCONN(3,NEDGES),NBOUND(3,NFACES),INDSUM(NEDGES)
      REAL LAMBDA,K,MU,IMP
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/WAVE/OMEGA,LAMBDA,K
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      CONST1=CMPLX(0.0,1.0/OMEGA)
      CHARGE=CMPLX(0.0,0.0)
      WRITE(11,101)
 101  FORMAT(X,/25X,'SURFACE CHARGE',/)
      WRITE(11,102)
 102  FORMAT(1X,'FACE NUMBER',10X,'CHARGE DENSITY (COULOMBS/SQ.METER)')
      WRITE(11,103)
 103  FORMAT(/20X,'REAL',11X,'IMAGINARY',8X,'MAGNITUDE',10X,'PHASE')
      DO 999 IFS=1,NFACES
C
C OBTAIN THE EDGES OF THE TRIANGLE.
C
      CALL FACEDG(NFACES,NBOUND,IFS,IS)
C
C OBTAIN THE VERTICES CONNECTED TO THESE EDGES.
C
      CALL FACVTX(NCONN,NEDGES,IS,NS)
C
C COMPUTE THE COORDINATES OF EACH VERTEX.
C
      CALL VTXCRD(DATNOD,NNODES,NS,DN)
C
      IF(NJCT.EQ.1)THEN
C
C TO FIND PARAMATERS ASSOCIATE WITH THIS JUNCTION
C
```

```
      CALL JUNPAR(JSF,DN,NS,IFS,ANGS,VSJUN,JSCOL,
     &      WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C
C ANGM IS THE ANGULAR DISTRIBUTION COEFFICIENCY OF MATCH TRIANGLE
C
      ELSE
      JSF=0
      ENDIF
C
C CALCULATE THE AREA OF THE TRIANGLE.
C
      AR1=(DN(2,2)-DN(1,2))*(DN(3,3)-DN(1,3))-(DN(3,2)-DN(1,2))*
     & (DN(2,3)-DN(1,3))
      AR2=(DN(2,3)-DN(1,3))*(DN(3,1)-DN(1,1))-(DN(3,3)-DN(1,3))*
     & (DN(2,1)-DN(1,1))
      AR3=(DN(2,1)-DN(1,1))*(DN(3,2)-DN(1,2))-(DN(3,1)-DN(1,1))*
     & (DN(2,2)-DN(1,2))
      AREA=SQRT(AR1**2+AR2**2+AR3**2)/2.0
C
C CALCULATE THE LENGTHS OF EACH SIDE.
C
        DO 8 I=1,3
           IP1=MOD(I,3)+1
           IM1=MOD(I+1,3)+1
             DO 7 J=1,3
7            DLM(J)=DN(IM1,J)-DN(IP1,J)
8       SM(I)=SIZE(DLM(1),DLM(2),DLM(3))
C
C COMPUTE THE CHARGE DENSITY ON THE TRIANGLE.
C
      CSUM=CMPLX(0.0,0.0)
            DO 460 ISL=1,3
              ISS=IS(ISL)
              MULTS=NCONN(3,ISS)
              IF(MULTS.NE.0)THEN
                IF(ISL.EQ.1)THEN
                  FLAG=SM(1)
                  IF(NCONN(1,IS(1)).EQ.NS(3))FLAG=-FLAG
                ELSEIF(ISL.EQ.2)THEN
                  FLAG=SM(2)
                  IF(NCONN(1,IS(2)).EQ.NS(1))FLAG=-FLAG
                ELSE
                  FLAG=SM(3)
                  IF(NCONN(1,IS(3)).EQ.NS(2))FLAG=-FLAG
                ENDIF
```

```
C FOR AN EDGE WITH MULTIPLICITY MULT, THE LOWEST NUMBERED FACE
C CONTRIBUTES TO MULT BASIS FUNCTIONS ASSOCIATED WITH THAT EDGE,
C WHILE EACH REMAINING FACE CONTRIBUTES TO ONE BASIS FUNCTION ASSOCIATED
C WITH THAT EDGE.
                CALL EDGMUL(IEDGF,MULT1,NEDGES,MULTS,ISS,IFS,JS1,JS2)
                                   INDS=INDSUM(ISS)
                DO 450 JS=JS1,JS2
                  IV=IV+1
                  ICOL=INDS+JS
 450            CSUM=CSUM+FLAG*CONST1*CI(ICOL)
              ENDIF
 460        CONTINUE
        IF(JSF.NE.0)THEN
          CSUM=CSUM+CONST1*CI(JSCOL)*ANGS
        ENDIF
      CHDEN=CSUM/CMPLX(AREA,0.0)
      RA1=REAL(CHDEN)
      RA2=AIMAG(CHDEN)
      RA3=CABS(CHDEN)
                  EPS=1.E-7
                  IF(RA2.EQ.0.)THEN
                     RA4=0.
                  ELSEIF(ABS(RA1/RA2).LT.EPS)THEN
                     RA4=90.
                  ELSE
                     RA4=ATAN2(RA2,RA1)/DEG2RAD
                  ENDIF
      WRITE(11,501) IFS,RA1,RA2,RA3,RA4
 501  FORMAT(2X,I4,5X,1E,2X,1E,2X,1E,2X,1E)
      CHARGE=CHARGE+CSUM
 999  CONTINUE
      WRITE(11,502) CHARGE
 502  FORMAT(/10X,'TOTAL CHARGE ON THE BODY= (',2E,1X,') COULOMBS')
      RETURN
      END
```

A.50 QWIRE

```
C
C======================================================================
      SUBROUTINE QWIRE(CI,NWNOD,NWSEG,NUNKNB,NUNKNT,WNODE,WIRSUM,NSEGC,
     $MULTW,MNJUN,NWJUN,INSEG,MXWMLT)
C----------------------------------------------------------------------
```

```
C THIS SUBROUTINE COMPUTES THE CHARGE DISTRIBUTION ON THE
C WIRE. THE CHARGE DENSITY IS COMPUTED AT THE CENTROID OF
C EACH SEGMENT.
C
      IMPLICIT COMPLEX (C)
C
      INTEGER WIRSUM(NWNOD),NSEGC(2,NWSEG),MULTW(NWNOD),NWJUN(MNJUN)
     &,INSEG(MXWMLT+1,NWNOD)
      REAL WNODE(3,NWNOD),SH(3)
      COMPLEX CI(NUNKNT)
      REAL LAMBDA,K,MU,IMP
      LOGICAL LOWS,LOWM,PLUS
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/WAVE/OMEGA,LAMBDA,K
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      CONST1=CMPLX(0.0,1.0/OMEGA)
      CHARGE=CMPLX(0.0,0.0)
      WRITE(11,101)
 101  FORMAT(X,/25X,'CHARGE DENSITY ON WIRE',/)
      WRITE(11,102)
 102  FORMAT(1X,'SEGMENT NUMBER',10X,'CHARGE DENSITY
     & (COULOMBS/SQ.METER)')
      WRITE(11,103)
 103  FORMAT(/20X,'REAL',11X,'IMAGINARY',8X,'MAGNITUDE',10X,'PHASE')
C
* LOOP OVER THE SOURCE SEGMENTS.
C
      DO 1000 NS=1,NWSEG
      CSUM=CMPLX(0.0,0.0)
          NSF=NSEGC(1,NS)
          NST=NSEGC(2,NS)
          DO 2 J=1,3
            SH(J)=(WNODE(J,NST)-WNODE(J,NSF))
 2        CONTINUE
          DEL=SQRT(SH(1)*SH(1)+SH(2)*SH(2)+SH(3)*SH(3))
C
* LOOP OVER NODES ATTACHED TO THE SEGMENT.
C
            DO 400 JNS=1,2
              NODES=NSEGC(JNS,NS)
              MULTS=MULTW(NODES)
              IF(MULTS.GT.0)THEN
C
* COMPUTE COLUMN INDEX FOR SOURCE SEGMENT.
C
```

```
                 INDC=WIRSUM(NODES)
C
*  DETERMINE WHETHER SEGMENT NS IS THE LOWEST SEGMENT ATTACHED TO NODE
*  NODES.LOOP OVER THE NUMBER OF SEGMENTS ATTACHED TO NS AT NODE NODES.
C
                 CALL NODMUL(INSEG,MXWMLT,NWNOD,NODES,MULTS,NS,JS1,JS2,
     >                     LOWS)
      IF(LOWS.AND.NODES.EQ.NWJUN(MNJUN)) THEN
      JS1=1
      JS2=1
      LOWS=.FALSE.
      ENDIF
                 DO 300 J=JS1,JS2
                   ICOL=INDC+J
                   IV=IV+1
                   IF(NODES.EQ.NSEGC(2,NS))THEN
                     PLUS=.TRUE.
                   ELSE
                     PLUS=.FALSE.
                   ENDIF
                   IF(LOWS)THEN
C
* OBTAIN THE ATTACHED SEGMENT.
C
                     NSEGAS=INSEG(J+1,NODES)
C
* SGN=+1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE SAME DIRECTION,
* SGN=-1 IF SEGMENT NS & ATTACHED SEGMENT RUN IN THE OPPOSITE DIRECTION
C
                     IF(NSEGC(2,NS).EQ.NSEGC(1,NSEGAS).OR.
     >                  NSEGC(1,NS).EQ.NSEGC(2,NSEGAS))THEN
                       SGN=1.
                     ELSE
                       SGN=-1.
                     ENDIF
                   ELSE
                     SGN=1.
                   ENDIF
C
C
* COMPUTE APPROPRIATE VECTOR AND SCALAR POTENTIALS.
C
                   IF(PLUS)THEN
C
C FOR PLUS SOURCE SEGMENT SET SIGN= (-1) TO VECTOR AND SCALAR POTENTIALS
```

```
C
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=-1.
                  ELSE
C
C FOR MINUS SOURCE SEGMENT SET SIGN= (+1) TO VECTOR POTENTIAL AND
C (-1) TO SCALAR POTENTIALS
C
      IF(NODES.EQ.NWJUN(MNJUN)) SGN=1.
                  ENDIF
        IF(JNS.EQ.2)SGN=-SGN
        CSUM=CSUM-CONST1*CI(ICOL)*SGN
300     CONTINUE
        ENDIF
400     CONTINUE
      CHDEN=CSUM/DEL
      RA1=REAL(CHDEN)
      RA2=AIMAG(CHDEN)
      RA3=CABS(CHDEN)
                  EPS=1.E-7
                  IF(RA2.EQ.O.)THEN
                  RA4=0.
                  ELSEIF(ABS(RA1/RA2).LT.EPS)THEN
                  RA4=90.
                  ELSE
                  RA4=ATAN2(RA2,RA1)/DEG2RAD
                  ENDIF
      WRITE(11,501) NS,RA1,RA2,RA3,RA4
 501  FORMAT(2X,I4,5X,1E,2X,1E,2X,1E,2X,1E)
      CHARGE=CHARGE+CSUM
1000  CONTINUE
      WRITE(11,502) CHARGE
 502  FORMAT(/10X,'TOTAL CHARGE ON THE WIRE= (',2E,1X,') COULOMBS')
      RETURN
      END
```

A.51 CPATT

```
C====================================================================
      COMPLEX FUNCTION CPATT(SP)
C--------------------------------------------------------------------
* INPUT:
*  RMK(J),J=1,2,3=K* THE X,Y,Z COMPONENTS OF THE MATCH POINT.
*  SH(J) J=1,2,3 = THE X,Y,Z COMPOMENTS OF THE UNIT VECTOR POINTING IN
```

```
*  THE SAME DIRECTION AS THE SOURCE SEGMENT.
*  RSK(J)= K* THE X,Y,Z COORDINATES OF THE THE SOURCE SEGMENT CENTROID
*  RADSK=K * THE SOURCE SEGMENT RADIUS.
*  RADSKS=RADSK*RADSK
*  SP IS K* THE DISTANCE ALONG THE SOURCE SEGMENT THAT RPRIME IS FROM
*  THE SOURCE SEGMENT CENTROID. A POSITIVE DISTANCE IS TOWARDS THE
*  ENDPOINT OF THE SOURCE SEGMENT, A NEGATIVE DISTANCE IS TOWARDS THE
*  INITIAL POINT OF THE SOURCE SEGMENT.
* OUTPUT:
*  CKMN=THE REDUCED KERNEL EVALUATED AT R=THE MATCH POINT AND
*  RPRIME(J)=RSK(J)-SP*SH(J).
C---------------------------------------------------------------------
      DIMENSION RMK(3),SH(3),RSK(3),D(3)
      COMMON/WKERNL/RSK,SH,RMK
C
      DO 5 J=1,3
        D(J)=RSK(J)-SP*SH(J)
 5    CONTINUE
      R=D(1)*RMK(1)+D(2)*RMK(2)+D(3)*RMK(3)
      CPATT=CEXP(CMPLX(0.,R))
      RETURN
      END
```

A.52 SGQADS

```
C======================================================================
      SUBROUTINE SGQADS(FCT,XL,XU,IQUAD,ANS)
C---------------------------------------------------------------------
C GAUSSIAN QUADRATURE INTEGRAL OVER WIRE SEGMENT FOR SELF TERM
* INPUTS:
*  FCT IS A COMPLEX FUNCTION.
*  IQUAD IS THE NUMBER OF INTEGRATION POINTS( IQUAD MUST BE 4,8 OR 16)
*  XL IS THE LOWER INTEGRATION LIMIT
*  XU IS THE UPPER INTEGRATION LIMIT
* OUTPUT:
*  ANS IS THE INTEGRAL OF FCT(X) FROM X=XL TO XU.
C---------------------------------------------------------------------
      COMPLEX FCT,ANS,FP,FM,CSUM
      REAL AC(2),AD(2),AE(4),AF(4),AG(8),AH(8)
      EXTERNAL FCT
      DATA AC(1),AC(2),AD(1),AD(2) /
     > .339981043584856,.861136311594053,
     > .652145154862546,.347854845137454/
```

```
      DATA AE(1),AE(2),AE(3),AE(4),AF(1),AF(2),AF(3),AF(4)/
     > .183434642495650,.525532409916329,
     > .796666477413627,.960289856497536,
     > .362683783378362,.313706645877887,
     > .222381034453374,.101228536290376/
      DATA AG/.095012509837637,.281603550779258,
     >.4508016777657227,.617876244402643,.755404408355003,
     >.865631202387831,.944575023073232,.989400934991649/
      DATA AH/.189450610455068,.182603415044923,
     >.169156519395002,.149595988816576,.124628971255533,
     >.095158511682492,.062253523938647,.027152459411754/
C
      CSUM=(0.,0.)
      DEL=.5*(XU-XL)
      XC=.5*(XL+XU)
      IF(IQUAD.EQ.4)THEN
C
          DO 20 J=1,2
            C=AC(J)*DEL
            FP=FCT(XC+C)
            FM=FCT(XC-C)
            CSUM=CSUM+AD(J)*(FP+FM)
 20       CONTINUE
      ELSEIF(IQUAD.EQ.8)THEN
C
          DO 200 J=1,4
            C=AE(J)*DEL
            FP=FCT(XC+C)
            FM=FCT(XC-C)
            CSUM=CSUM+AF(J)*(FP+FM)
 200      CONTINUE
      ELSEIF(IQUAD.EQ.16)THEN
          DO 300 J=1,4
            C=AE(J)*DEL
            FP=FCT(XC+C)
            FM=FCT(XC-C)
            CSUM=CSUM+AF(J)*(FP+FM)
 300      CONTINUE
        ELSE
        WRITE(4,10)IQUAD
 10     FORMAT(1X,'WARNING IN QG IQUAD OUT OF RANGE,IQUAD=',I5)
        STOP
        ENDIF
      ANS=CSUM*DEL
```

```
      RETURN
      END
```

A.53 SEGQAD

```
C======================================================================
      SUBROUTINE SEGQAD(FCT,DEL,IQUAD,ANS)
C----------------------------------------------------------------------
C GAUSSIAN QUADRATURE INTEGRAL OVER WIRE SEGMENT
* INPUTS:
*  FCT IS A COMPLEX FUNCTION.
*  DEL IS AN INTEGRATION LIMIT.
*  IQUAD IS THE NUMBER OF INTEGRATION POINTS(FOR NOW IQUAD MUST BE 4)
* OUTPUT:
*  ANS(J)=1./DEL * THE INTEGRAL FROM SP=-DEL/2 TO DEL/2
*         FCT(SP)*VEC(J) D(SP)
*  WHERE VEC(1)=1,VEC(2)=SP,VEC(3)=DEL-SP
C----------------------------------------------------------------------
      COMPLEX FCT,ANS(3),FP,FM
      REAL AC(2),AD(2),AE(4),AF(4)
      EXTERNAL FCT
      DATA AC(1),AC(2),AD(1),AD(2) /
     >             .339981043584856,.861136311594053,
     >             .652145154862546,.347854845137454/
      DATA AE(1),AE(2),AE(3),AE(4),AF(1),AF(2),AF(3),AF(4)/
     >             .183434642495650,.525532409916329,
     >             .796666477413627,.960289856497536,
     >             .362683783378362,.313706645877887,
     >             .222381034453374,.101228536290376/
C
      DEL2=DEL/2.
      DO 5 J=1,3
        ANS(J)=(0.,0.)
 5    CONTINUE
      IF(IQUAD.EQ.4)THEN
          DO 40 J=1,2
            C=AC(J)*DEL2
            FP=FCT(C)
            FM=FCT(-C)
            ANS(1)=ANS(1)+AD(J)*(FP+FM)
            ANS(2)=ANS(2)+AD(J)*(FP*C-FM*C)
 40       CONTINUE
          ANS(1)=DEL2*ANS(1)
```

```
          ANS(2)=.5*(ANS(2)+ANS(1))
          ANS(3)=ANS(1)-ANS(2)
      ELSEIF(IQUAD.EQ.8)THEN
          DO 400 J=1,4
            C=AE(J)*DEL2
            FP=FCT(C)
            FM=FCT(-C)
            ANS(1)=ANS(1)+AF(J)*(FP+FM)
            ANS(2)=ANS(2)+AF(J)*(FP*C-FM*C)
400       CONTINUE
          ANS(1)=DEL2*ANS(1)
          ANS(2)=.5*(ANS(2)+ANS(1))
          ANS(3)=ANS(1)-ANS(2)
      ELSE
        WRITE(4,10)IQUAD
10      FORMAT(1X,'WARNING IN QUAD IQUAD OUT OF RANGE,IQUAD=',I5)
        STOP
      ENDIF
      RETURN
      END
```

A.54 WCUMUL

```
C=================================================================
      SUBROUTINE WCUMUL(NWNOD,NUNKNB,MULTW,WIRSUM)
C-----------------------------------------------------------------
C CUMULATE MULTIPLICITY OF WIRE NODE
* INPUT:
*  NWNOD=THE NUMBER OF WIRE UNKNOWNS.
*  NUNKNB=THE NUMBER OF BODY UNKNOWNS.
*  MULTW(N)=THE MULTIPLICITY OF THE NTH WIRE NODE.
* OUTPUT:
*  WIRSUM(I)=NUNKNB+THE SUM OF WIRE NODE MULTIPLICTIES UP TO
*  (BUT NOT INCLUDING)THE NODE I.
C-----------------------------------------------------------------
      INTEGER MULTW(NWNOD),WIRSUM(NWNOD)
      WIRSUM(1)=0
      DO 10 I=2 NWNOD
        WIRSUM(I)=MULTW(I-1)+WIRSUM(I-1)
 10   CONTINUE
      DO 20 I=1,NWNOD
        WIRSUM(I)=WIRSUM(I)+NUNKNB
 20   CONTINUE
```

```
      RETURN
      END
```

A.55 NODMUL

```
C=====================================================================
      SUBROUTINE NODMUL(INSEG,MXWMLT,NWNOD,NODE,MULTN,NSEG,JN1,JN2,LOW)
C---------------------------------------------------------------------
C MAPPING FROM NODE TO MULTIPLICITY
* INPUT:
*  INSEG(M,N) M=1,...,MULTW(N)+1 CONTAIN THE WIRE SEGMENTS ATTACHED
*  TO THE NTH NODE.
*  MXWMLT=THE MAXIMUM MULTIPLICITY OF ANY WIRE NODE.
*  NWNOD THE NUMBER OF WIRE NODES.
*  NODE= THE WIRE NODE NUMBER.
*  MULTN=THE MULTIPLICITY OF THE NODE 'NODE'
*  NSEG= THE SEGMENT NUMBER
* OUTPUT:JN1 JN2
*  IF NSEG IS THE LOWEST NUMBERED SEGMENT ATTACHED TO NODE 'NODE'
*  THEN JN1=1 AND JN2=MULTN
*  ELSE IF NSEG IS THE ITH SEGMENT(>FIRST) ATTACHED TO NODE 'NODE'
*  THEN JN1=JN2=I-1
*  ENDIF
C-----------------------------------------------------------------
      INTEGER INSEG(MXWMLT+1,NWNOD)
      LOGICAL LOW
C
      IF(INSEG(1,NODE).EQ.NSEG)THEN
        LOW=.TRUE.
        JN1=1
        JN2=MULTN
      ELSE
        LOW=.FALSE.
        M1=MULTN+1
        DO 10 I=2,M1
          IF(NSEG.EQ.INSEG(I,NODE))THEN
            I1=I-1
            JN1=I1
            JN2=I1
            GO TO 11
          ENDIF
 10     CONTINUE
 11     CONTINUE
```

```
      ENDIF
      RETURN
      END
```

A.56 WIROUT

```
C==============================================================
      SUBROUTINE WIROUT(CV,NUNKNT,NUNKNB,MULTW,NWNOD)
C--------------------------------------------------------------
C THIS SUBROUTINE PRINTS OUTPUT DATA ASSOCIATED WITH WIRES
C
      COMPLEX CV(NUNKNT)
      INTEGER MULTW(NWNOD)
      COMMON/F/FREQ
      DEG2RAD=3.14159265358979/180.
C
* WRITE THE CURRENT DENSITY TABLE.
C
          WRITE(9,22)
 22       FORMAT(//28X,'SURFACE CURRENTS'/)
          WRITE(9,23)
 23       FORMAT(1X,'EDGE NUMBER ',13X,'CURRENT DENSITY (AMPS/METER)')
          WRITE(9,24)
 24       FORMAT
     >        (14X,'REAL',9X,'IMAGINARY',7X,'MAGNITUDE',7X,'PHASE(DEG)')
          CO=(0.,0.)
          K1=0+NUNKNB
          DO 50 I50=1,NWNOD
            IF(MULTW(I50).EQ.0)THEN
              WRITE(9,101)I50,CO,0.
              WRITE(4,101)I50,CO,0.
              A=0.
            ELSE
              DO 35 I35=1,MULTW(I50)
                K1=K1+1
                RA1=REAL(CV(K1))
                RA2=AIMAG(CV(K1))
                RA3=CABS(CV(K1))
                IF(ABS(RA1).LT.1.E-10)THEN
                RA4=90.
                ELSE
                RA4=ATAN2(RA2,RA1)/DEG2RAD
                ENDIF
```

```
               WRITE(9,101) I50,RA1,RA2,RA3,RA4
               WRITE(4,101) I50,RA1,RA2,RA3,RA4
 35          CONTINUE
           ENDIF
 50      CONTINUE
 101     FORMAT(2X,I4,2X,3(2X,E12.5,2X),F12.3)
C
C PRINT OUT CURRENT ON THE JUNCTION NODE
C IT IS INPUT CONDUCTANCE IF SET RIGHT HAND SIDE CV(NUNKNT)=1
C
C      WRITE(11,*)FQ,CV(NUNKNT)
C      WRITE(11,*)FQ,CV(NUNKNB+1)
C102     FORMAT(X,F6.4,',',E15.5,',',E15.5,',')
      RETURN
      END
```

A.57 FNDJUN

```
C==================================================================
      SUBROUTINE FNDJUN(WNODE,NWNOD,DATNOD,NNODES,MNJUN,NWJUN,NBJUN)
C------------------------------------------------------------------
C PURPOSE:
C FOR BODY AND WIRE, FIND OUT WHICH NODE IS JUNCTION
C
C INPUT:
C MNJUN: NUMBER OF JUNCTION
C OUTPUT:
C NWJUN(I):WIRE NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C NBJUN(I):BODY NODE NUMBER OF THE ITH JUNCTION I=1,MNJUN
C--------------------------------------------------------------
      REAL WNODE(3,NWNOD),DATNOD(3,NNODES)
      INTEGER NWJUN(MNJUN),NBJUN(MNJUN)
      NJ=0
C
C LOOP OVER EACH WIRE NODE AND BODY NODE
C
      EPS=1.E-4
      DO 10 NW=1,NWNOD
      DO 10 N=1,NNODES
C
C IF WIRE NODE AND BODY NODE AT THE SAME POINT IT IS A JUNCTION POINT
C
      E1=ABS(WNODE(1,NW)-DATNOD(1,N))
```

```
      E2=ABS(WNODE(2,NW)-DATNOD(2,N))
      E3=ABS(WNODE(3,NW)-DATNOD(3,N))
      IF(E1.GT.EPS.OR.E2.GT.EPS.OR.E3.GT.EPS) GO TO 10
      NJ=NJ+1
      NWJUN(NJ)=NW
      NBJUN(NJ)=N
10    CONTINUE
      WRITE(3,*)' NUMBER OF JUNCTION = ',NJ
      DO 20 NN=1,NJ
20    WRITE(3,*)' ON WIRE NODE = ',NWJUN(NN)

      RETURN
      END
```

A.58 JUNFAC

```
C===================================================================
      SUBROUTINE JUNFAC(NBJUN,MNJUN,NBOUND,NFACES,NCONN,NEDGES,
     &  NJFACE,MNJFACE,MIFACE)
C-------------------------------------------------------------------
C PURPOSE:
C FOR EACH JUNCTION, FIND OUT THE PATCHES ATTACH TO?
C
C INPUT:
C NBJUN(I):NODE NUMBER OF THE ITH JUNCTION POINT. I=1,MNJUN
C MNJFACE:MAXIMUN NUMBER OF FACE ATTACHING TO JUNCTION POINT
C OUTPUT:
C NJFACE(I,J):FACE NUMBER OF THE JTH FACE ATTACHING TO THE ITH JUNCTION
C POINT. I=1,MNJUN, J=1,MIFACE(I)
C MIFACE(I):MAXIMUN NUMBER OF FACE ATTACHING TO THE ITH JUNCTION POINT.
C---------------------------------------------------------------------
      INTEGER NBJUN(MNJUN),NCONN(3,NEDGES),NBOUND(3,NFACES)
     &      ,NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),IE(3),NV(3)
C
C LOOP OVER EACH JUNCTION POINT
C
      EPS=1.E-3
      DO 10 NJ=1,MNJUN
      I=0
C
C CHECK IF THIS FACE ATTACHING TO JUNCTION POINT
C
      DO 20 N=1,NFACES
```

```
      CALL FACEDG(NFACES,NBOUND,N,IE)
      CALL FACVTX(NCONN,NEDGES,IE,NV)
      E1=ABS(NV(1)-NBJUN(NJ))
      E2=ABS(NV(2)-NBJUN(NJ))
      E3=ABS(NV(3)-NBJUN(NJ))
      IF(E1.GT.EPS.AND.E2.GT.EPS.AND.E3.GT.EPS) GO TO 20
      I=I+1
      NJFACE(NJ,I)=N
20    CONTINUE
      MIFACE(NJ)=I
10    CONTINUE
      RETURN
      END
```

A.59 JANGLE

```
C=======================================================================
      SUBROUTINE JANGLE(DATNOD,NNODES,NBJUN,MNJUN,NBOUND,NFACES,NCONN,
     &      NEDGES,NJFACE,MNJFACE,MIFACE,ANG)
C-----------------------------------------------------------------------
C PURPOSE: FOR EACH JUNCTION, COMPUTE VERTEX ANGLE OF EACH ATTACHED
C TRIANGLES.
C OUTPUT:
C ANG(I,J):ANGLE FACTOR OF THE JTH PATCH ATTACHING TO THE ITH JUNCTION
C POINT
C SANG(I):THE SUM OF THE VERTEX ANGLE OF THE ITH JUNCTION POINT
C---------------------------------------------------------------------
      REAL DATNOD(3,NNODES),SANG(40),ANG(MNJUN,MNJFACE),DN(3,3)
     &      ,VP(3),VM(3)
      INTEGER NBJUN(MNJUN),NCONN(3,NEDGES),NBOUND(3,NFACES)
     &      ,NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NV(3),IE(3)
C
      SIZE(A,B,C)=SQRT(A*A+B*B+C*C)
C
C LOOP OVER EACH JUNCTION POINT
C
      DO 10 I=1,MNJUN
      SANG(I)=0.
C
C LOOP OVER EACH ATTACHED FACE
C
      DO 10 J=1,MIFACE(I)
      IJ=NJFACE(I,J)
```

```
      CALL FACEDG(NFACES,NBOUND,IJ,IE)
C
C FROM THESE EDGES, OBTAIN THE VERTICES OF THE TRIANGLE.
C
      CALL FACVTX(NCONN,NEDGES,IE,NV)
C
C CALCULATE THE COORDINATES OF EACH VERTEX.
C
      CALL VTXCRD(DATNOD,NNODES,NV,DN)
      DO 20 II=1,3
20    IF(NV(II).EQ.NBJUN(I)) GO TO 30
30    IP1=MOD(II,3)+1
      IM1=MOD(IP1,3)+1
      DO 40 JJ=1,3
      VP(JJ)=DN(IP1,JJ)-DN(II,JJ)
40    VM(JJ)=DN(IM1,JJ)-DN(II,JJ)
      EP=SIZE(VP(1),VP(2),VP(3))
      EM=SIZE(VM(1),VM(2),VM(3))
      DOT=VP(1)*VM(1)+VP(2)*VM(2)+VP(3)*VM(3)
C
C A DOT B = LAL LBL COS(ANG)
C
      ANG(I,J)=ACOS(DOT/EP/EM)
      SANG(I)=SANG(I)+ANG(I,J)
10    CONTINUE
      DO 100 I=1,MNJUN
      DO 100 J=1,MIFACE(I)
100   ANG(I,J)=ANG(I,J)/SANG(I)
      RETURN
      END
```

A.60 JUNPAR

```
C===================================================================
      SUBROUTINE JUNPAR(JFLAG,DATNOD,NODE,IFACE,AANGLE,VETJUN,INDEX,
     &      WIRSUM,MNJUN,MNJFACE,NWNOD,ANG,NJFACE,MIFACE,NWJUN,NBJUN)
C-------------------------------------------------------------------
C PURPOSE:
C FIND OUT GEOMETRY PARAMETERS ASSOCIATE WITH THIS JUNCTION PATCH
C
C INPUT:
C DATNOD(I,J):J=1,3 ARE THE X,Y,Z COORDINATES OF THE ITH VERTEX OF THIS
C PATCH
```

```
C NODE(I):I=1,3 NODE NUMBER OF THE ITH VERTEX OF THIS PATCH
C IFACE:FACE NUMBER OF THIS PATCH
C OUTPUT:
C ANGLE:VERTEX ANGLE FACTOR OF THIS PATCH ATTACHING TO THE JUNCTION
C POINT
C VETJUN(J):J=1,3 TESTING VECTOR RUNNING FROM THE CENTER TO THE
C JUNCTION VERTEX
C-----------------------------------------------------------------
      REAL ANG(MNJUN,MNJFACE),DATNOD(3,3),DATNODC(3),VETJUN(3)
      INTEGER NJFACE(MNJUN,MNJFACE),MIFACE(MNJUN),NBJUN(MNJUN),
     &      NWJUN(MNJUN),NODE(3),WIRSUM(NWNOD)
C
C FIND JUNCTION VERTEX AND CORRESPONDING JUNCTION NUMBER
C
      DO 10 INODE=1,3
      DO 10 JUNNO=1,MNJUN
      IF(NODE(INODE).EQ.NBJUN(JUNNO)) GO TO 20
10    CONTINUE
C
C SET JFLAG=0, THERE IS NOT ANY JUNCTION ON THIS PATCH
C
      JFLAG=0
      GO TO 100
C
C SET JFLAG= WHICH VERTEX OF THIS JUNCTION PATCH,
C IF THERE IS ANY JUNCTION ON THIS PATCH
C
20      JFLAG=INODE
C
C DETERMINE ROW(MATCHING) OR COLUMN(SOURCE) LOCATION IN THE MATRIX
C
        INDEX=WIRSUM(NWJUN(JUNNO))+1
C
C FIND THE VERTEX ANGLE OF THE JUNCTION PATCH
C
        DO 30 M=1,MIFACE(JUNNO)
        IF(NJFACE(JUNNO,M).EQ.IFACE) GO TO 40
30      CONTINUE
        WRITE(6,*)' ERROR : CAN NOT FIND JUNCTION FACE '
40      AANGLE=ANG(JUNNO,M)
C
C DATNODC(J),J=1,3 IS THE CENTER OF THE PATCH
C
        DO 50 JJ=1,3
C
```

```
C COMPUTE THE VECTOR OF TESTING PATH
C
       DATNODC(JJ)=(DATNOD(1,JJ)+DATNOD(2,JJ)+DATNOD(3,JJ))/3.
50     VETJUN(JJ)=DATNOD(INODE,JJ)-DATNODC(JJ)
100    RETURN
      END
```

A.61 FACPAR

```
C=====================================================================
      SUBROUTINE FACPAR(JSF,RK,RMK)
C---------------------------------------------------------------------
C THIS SUBROUTINE COMPUTES MOST PARAMETERS FOR COMPUTING VECTOR AND SCALAR
C POTENTIALS
C JSF = 1,2 OR 3 IS JUNCTION VERTEX OF THE TRIANGLE
C RK(I,J) IS THE VERTEX COORDINATE OF THE SOURCE TRIANGLE
C RMK(J) IS THE MATCHING POINT OR CENTER OF THE MATCHING TRIANGLE
C---------------------------------------------------------------------
      IMPLICIT COMPLEX (C)
      DIMENSION RMKO(3),RI(3,3),P(3,3),PH(3),RIL(3),URI(3,3),RR2(3)
     $      ,VH(3,3),RR(3),RRR(3)
      DIMENSION H(3),RK(3,3),RMK(3),UN(3),UL(3,3),UH(3,3),AL(3),DL(3,3)
      COMMON/CONJ/XSING2
      COMMON/MINMAX/RLMINK,RLMAXK
      COMMON/JUN/RI,P,PH,RR,RR2,RIL,URI,VH
      COMMON/PARA/DL,DET,H,AL,UL,UH,RMKO,UN,DPERPK
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
C
C HAT N = [(VET R(2)-VET R(1)) X (VET R(3)-VET R(1))] /
C ABS[(VET R(2)-VET R(1)) X (VET R(3)- VET R(1))]
C
      PK=JSF
      DO 10 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      DO 20 J=1,3
20    DL(I,J)=RK(IM1,J)-RK(IP1,J)
      AL(I)=SIZE(DL(I,1),DL(I,2),DL(I,3))
      DO 30 J=1,3
30    UL(I,J)=DL(I,J)/AL(I)
10    CONTINUE
C
      RLMINK=AMIN1(AL(1),AL(2),AL(3))
```

```
      RLMAXK=AMAX1(AL(1),AL(2),AL(3))
C
      DO 40 J=1,3
      JP1=MOD(J,3)+1
      JM1=MOD(J+1,3)+1
40    UN(J)=DL(3,JP1)*DL(1,JM1)-DL(3,JM1)*DL(1,JP1)
      DET=SIZE(UN(1),UN(2),UN(3))
      DO 50 J=1,3
      UN(J)=UN(J)/DET
50    H(J)=DET/AL(J)
C
C VH(I,J)= THE VECTOR OF THE HEIGHT H(I)
C
      DO 70 I=1,3
      DO 70 J=1,3
      JP1=MOD(J,3)+1
      JM1=MOD(J+1,3)+1
      UH(I,J)=UL(I,JP1)*UN(JM1)-UL(I,JM1)*UN(JP1)
70    VH(I,J)=H(I)*UH(I,J)
      DPERPK=0.
      DO 80 J=1,3
80    DPERPK=DPERPK+UN(J)*(RMK(J)-RK(1,J))
      DO 90 J=1,3
90    RMKO(J)=RMK(J)-DPERPK*UN(J)
      DPERPK=ABS(DPERPK)
      DO 100 I=1,3
      DO 110 J=1,3
110   RI(I,J)=RMK(J)-RK(I,J)
      RIL(I)=SIZE(RI(I,1),RI(I,2),RI(I,3))
      RIH=0.
      DO 120 J=1,3
      URI(I,J)=RI(I,J)/RIL(I)
120   RIH=RIH+URI(I,J)*UH(I,J)
      RRR(I)=RIH
      RR(I)=RIL(I)*RIH
      RR2(I)=RR(I)*RR(I)
22    FORMAT(3X,3E15.5)
      DO 130 J=1,3
130   P(I,J)=RMKO(J)-RK(I,J)
      PDH=0.
      DO 140 J=1,3
140   PDH=PDH+P(I,J)*UH(I,J)
      PH(I)=PDH
100   CONTINUE
C
```

```
C IF RI IS NEAR PERPENDICULAR TO HI, SET XSING2=1.
C
      IF(JSF.NE.0)THEN
      IF(RRR(JSF).LT.1.E-6) THEN
      XSING2=1.
      ELSE
      XSING2=0.
      ENDIF
      ENDIF
      RETURN
      END
```

A.62 ADWMUL

```
C==============================================================
      SUBROUTINE ADWMUL(NWNOD,WNODE,MULTW,NWUNKS)
C--------------------------------------------------------------
C ADJUST MULTIPLICITY OF WIRE NODE
C INPUT:
C  NWNOD=THE NUMBER OF WIRES NODES.
C  NWUNKS=THE NUMBER OF WIRES UNKNOWNS BEFORE CONSIDERING THE
C     GROUND PLANE ATTACHMENTS.
C  WNODE(I,N)=THE X,Y,Z COMPONENTS(I=1,2,3) OF THE NTH NODE N=1,NWNOD.
C     MULTW(N)= THE MULTIPLICITY OF THE NTH NODE N=1,NWNOD(BEFORE ANY GROUND
C     PLANE ATTACHMENTS ARE CONSIDERED).
C
C OUTPUT:
C  FOR EACH NODE IN THAT IS CONNECTED TO A P.E.C. GROUND PLANE AND IS
C  NOT CONNECTED TO A P.M.C. GROUND PLANE, ITS MULTIPLICITY(MULTW(IN))
C  AND THE NUMBER OF WIRES UNKNOWNS(NWUNKS) ARE INCRIMENTED BY 1.
C  THE NODE CONNECTION LIST WITH MULTIPLICITIES IS OUTPUTTED
C  AFTER ACCOUNTING FOR ALL GROUND PLANE ATTACHMENTS.
C-----------------------------------------------------------------
      DIMENSION WNODE(3,NWNOD),MULTW(NWNOD),IGNDP(3),DM(3)
      COMMON/GPLANE/NGNDP,IGNDP
      IF(NGNDP.GT.0)THEN
       GLIMT=1.E-4
       DO 100 IN=1,NWNOD
       DO 2 I=1,3
2      DM(I)=ABS(WNODE(I,IN))
          IX=0
          IY=0
          IZ=0
```

```
        IF(DM(1).LE.GLIMT)IX=IGNDP(1)
        IF(IX.NE.1)THEN
          IF(DM(2).LE.GLIMT)IY=IGNDP(2)
          IF(IY.NE.1.AND.DM(3).LE.GLIMT)IZ=IGNDP(3)
        ENDIF
        IMAX=AMAXO(IX,IY,IZ)
        IF(IMAX.NE.1)THEN
          IMIN=AMINO(IX,IY,IZ)
          NWUNKS=NWUNKS-IMIN
          MULTW(IN)=MULTW(IN)-IMIN
        ENDIF
100   CONTINUE
      ENDIF
      RETURN
      END
```

A.63 POTBOD

```
C=============================================================
      SUBROUTINE POTBOD(JSF,RK,RMK,C,CA,CAJ,IPAT)
C-------------------------------------------------------------
C COMPUTE POTENTIALS ASSOCIATED WITH BODY FACE
C     INPUT:
C     RK(J,I) I=1,2,3 DENOTES K*THE X,Y,Z COORDINATES OF THE JTH
C     VERTEX OF THE SOURCE TRIANGLE.(K=THE WAVE NUMBER)
C     RMK(I) I=1,2,3 DENOTE THE X,Y,Z COORDINATES OF THE MATCH POINT.
C     CONSTANTS PASSED THROUGH COMMON/GPLANE/
C     NGNDP=0,1,2,OR 3 THE NUMBER OF IMAGE PLANES.
C      IGNDP(I)=0  NO GROUND PLANES;
C               -1 A P.E.C. GROUND PLANE;
C                1 A P.M.C. GROUND PLANE.
C                I=1,2,3 DENOTES THE X=0,Y=0,ANDZ=0 GROUND PLANES.
C      OUTPUT:
C     AL(I),I=1,3 DENOTE K* THE LENGTHS OF THE SOURCE TRIANGLES SIDES
C     OPPOSITE THE 1 2 3 LOCAL VERTICIES RESPECTIVELY.
C     CI(I),I=1,3 IS
C     C=CI(1)+CI(2)+CI(3)
C     SCALAR POTENTIAL =-AL(I)*C/(2.*PI*OMEGA*EPSO*I) I=SQRT(-1.)
C     AL(I) IS THE LENGTH OF THE ITH SIDE OF THE SOURCE TRIANGLE *K
C     VECTOR POTENTIAL(I)=(MUO*AL(I)/(4*PI*K))*(CI(IP1)*DL(IM1,J)-
C     CI(IM1)*DL(IP1,J))
C-------------------------------------------------------------
      COMPLEX CI(3),C,CPP,CMM,CA(3,3),CAJ(3)
```

```
C
C VARIABLES ASSOCIATED WITH IMAGE PATCH
    $,CII(3),CPPI,CMMI
C
      DIMENSION RK(3,3),RMK(3),IGNDP(3)
      COMMON/GPLANE/NGNDP,IGNDP
      CALL FACPAR(JSF,RK,RMK)
      CALL PD3FAC(JSF,RK,RMK,C,CA,CAJ,IPAT)
       IF(NGNDP.GT.0)THEN
        DO 20 I=1,3
          IF(IGNDP(I).NE.0)CALL BIMAGE(JSF,RK,RMK,C,CA,CAJ,I,0,0,IPAT)
 20     CONTINUE
        IF(NGNDP.GE.2)THEN
          IF(IGNDP(1).EQ.0)THEN
            CALL BIMAGE(JSF,RK,RMK,C,CA,CAJ,0,2,3,IPAT)
          ELSEIF(IGNDP(2).EQ.0)THEN
            CALL BIMAGE(JSF,RK,RMK,C,CA,CAJ,3,1,0,IPAT)
          ELSE
            CALL BIMAGE(JSF,RK,RMK,C,CA,CAJ,2,1,0,IPAT)
            IF(IGNDP(3).NE.0)THEN
              CALL BIMAGE(JSF,RK,RMK,C,CA,CAJ,3,2,0,IPAT)
              CALL BIMAGE(JSF,RK,RMK,C,CA,CAJ,3,1,0,IPAT)
            ENDIF
          ENDIF
          IF(NGNDP.GE.3)CALL BIMAGE(
     $                 JSF,RK,RMK,C,CA,CAJ,3,2,1,IPAT)
        ENDIF
      ENDIF
      RETURN
      END
```

A.64 PD3FAC

```
C=====================================================================
      SUBROUTINE PD3FAC(JSF,RK,RMK,C,CA,CAJ,IPAT)
C----------------------------------------------------------------------
C POTENTIAL INTEGRAL OF DYNAMIC 3-D GREEN'S FUNCTION OVER FACE
C INPUT:
C  RK(J,I) I=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE JTH VERTEX
C  OF THE SOURCE TRIANGLE.
C  RMK(I) I=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE MATCH POINT.
C  K= THE WAVE NUMBER.
C  RATIO1,RATIO2,RATIO3 ARE TEST PARAMETERS THAT DETERMINE THE METHOD OF
```

```
C  INTEGRATION.
C  TO EXPLAIN THIS TEST DEFINE :
C  RAT=(THE DISTANCE TO THE SOURCE TRIANGLE'S CENTROID FROM THE
C  MATCH POINT)/THE SOURCE TRIANGLE'S MAXIMUM EDGE LENGTH.
C  RATIO=RAT*RAT.
C  IF RATIO.LE.RATIO1, 7 POINT QUADRATURE AND ANALYTICAL TREATMENT OF
C  SINGULARITIES IS PERFORMED.
C  IF RATIO1.LT.RATIO.LE.RATIO2 7 POINT QUADRATURE IS USED.
C  IF RATIO2.LT.RATIO.LE.RATIO3 3 POINT QUADRATURE IS USED.
C  IF RATIO3.LT.RATIO 1 POINT QUADRATURE IS USED.
C OUTPUT:
C  TO DEFINE THE REMAINING OUTPUTS WE INTRODUCE THE NORMALIZED
C  AREA COORDINATES (ZETA,XSI,ETA) FOR THE SOURCE TRIANGLE.
C  (ZETA,XSI,ETA)=(1,0,0) CORRESPONDS TO VERTEX 1.
C  (ZETA,XSI,ETA)=(0,1,0) CORRESPONDS TO VERTEX 2.
C  (ZETA,XSI,ETA)=(0,0,1) CORRESPONDS TO VERTEX 3.
C  ZETA=1-XSI-ETA.
C  THE NORMALIZED SOURCE TRIANGLE IS DEFINED BY: (XSI,ETA) WHERE
C  XSI VARIES FROM 0 TO 1-ETA AND ETA VARIES FROM 0 TO 1.
C  THE REMAINING OUTPUTS ARE C AND CVEC WHERE
C  C= THE DOUBLE INTEGRAL OVER THE NORMALIZED SOURCE TRIANGLE OF
C     CEXP(-I*DK)/DK D(XSI) D(ETA)
C  WHERE DK= K*  THE DISTANCE FROM THE SOURCE POINT TO THE MATCH POINT.
C  CVEC(I)=RK(1,I)*(C-CXSI-CETA)+RK(2,I)*CXSI+RK(3,I)*CETA I=1,2,3
C  WHERE CXSI AND CETA ARE THE INTEGRALS OVER THE NORMALIZED SOURCE
C  TRIANGLE OF:
C  CEXP(-I*DK)/DK TIMES XSI AND ETA RESPECTIVELY D(XSI) D(ETA).
C
C  THE VECTOR AND SCALAR POTENTIALS DUE TO A BASIS FUNCTION THAT
C  FLOWS OUTWARD FROM THE NTH EDGE OF THE SOURCE TRIANGLE ARE GIVEN
C  BY VEC POTENTIAL(I)=(MUO*RLK'SUB'N/(4*PI*K)*(CVEC(I)-RK(N,I)*C)
C  I=1,2,3.
C  SCALAR POTENTIAL=-RLK'SUB'N*C/(2*PI*OMEGA*EPSO*I) I=SQRT(-1.)
C  RLK'SUB'N IS K* THE LENGTH OF THE NTH SIDE OF THE SOURCE TRIANGLE.
C-----------------------------------------------------------------
      IMPLICIT COMPLEX (C)
      DIMENSION RK(3,3),RMK(3),RCK(3),SINGV(3),RMC(3),DL(3,3)
     &             ,SINGT(3),SP2(3),SM2(3),CI(3),CA(3,3),CAJ(3)
     &             ,H(3),V(3),AL(3)
      COMMON/MINMAX/RLMINK,RLMAXK
      COMMON/TEST/RATIO1,RATIO2,RATIO3
      COMMON/PARA/DL,DET,H,AL
      DATA RATIO1,RATIO2,RATIO3/1.,9.,100./
C
      CRX(X)=CMPLX(X,0.)
```

```
        JI=JI+1
C
        IF(IPAT.GT.0)THEN
        XSING=0.
        IF(IPAT.EQ.1)IQUAD=3
        IF(IPAT.EQ.2)IQUAD=1
        ELSE
      DO 2 J=1,3
      RCK(J)=(RK(1,J)+RK(2,J)+RK(3,J))/3.
2      RMC(J)=RMK(J)-RCK(J)
      RATIO=(RMC(1)*RMC(1)+RMC(2)*RMC(2)+RMC(3)*RMC(3))/(RLMAXK*RLMAXK)
      IF(RATIO.LE.RATIO1)THEN
        XSING=1.
        IQUAD=7
      ELSE
        XSING=0.
        IF(RATIO.LE.RATIO2)THEN
          IQUAD=7
        ELSEIF(RATIO.LE.RATIO3)THEN
          IQUAD=3
        ELSE
          IQUAD=1
        ENDIF
      ENDIF
      ENDIF
C
      CALL FACQAD(JSF,IQUAD,XSING,RK,RMK,RLMINK,C,CIXSI,CIETA,CPP,CMM
     &,IPAT)
C
      CI(1)=C-CIXSI-CIETA
      CI(2)=CIXSI
      CI(3)=CIETA
      IF(XSING.EQ.1.)THEN
      DO 111 I=1,3
      SP2(I)=0.
111      SM2(I)=0.
C
        CALL PS3FAC(JSF,RK,SINGT,SP2,SM2)
C
      DO 6 I=1,3
6       CI(I)=CI(I)+SINGT(I)
      IF(JSF.NE.0)THEN
      CPP=CPP+CRX(SP2(JSF))
      CMM=CMM+CRX(SM2(JSF))
      ENDIF
```

```
      ENDIF
      C=CI(1)+CI(2)+CI(3)
      DO 8 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(IP1,3)+1
      DO 8 J=1,3
8      CA(I,J)=CI(IP1)*DL(IM1,J)-CI(IM1)*DL(IP1,J)
      IF(JSF.NE.0)THEN
      IP1=MOD(JSF,3)+1
      IM1=MOD(IP1,3)+1
      DO 20 J=1,3
20    CAJ(J)=DET*H(JSF)*(CPP*DL(IM1,J)-CMM*DL(IP1,J))
      ENDIF
      RETURN
      END
```

A.65 BIMAGE

```
C=====================================================================
      SUBROUTINE BIMAGE(JSF,RK,RMK,C,CA,CAJ,I1,I2,I3,IPAT)
C---------------------------------------------------------------------
C  INPUT:
C     RK(J,I) I=1,2,3 DENOTES K*THE X,Y,Z COORDINATES OF THE JTH
C     VERTEX OF THE SOURCE TRIANGLE.
C     RMK(I) I=1,2,3 DENOTE K* THE X,Y,Z COORDINATES OF THE MATCH POINT
C     RLK1,RLK2,RLK3 DENOTE K*THE LENGTHS OF THE EDGES
C     OPPOSITE THE 1,2,3 VERTICIES OF THE SOURCE TRIANGLE.
C     IJ J=1,2,3 DENOTES : 0 IMAGE PLANES IF IJ=0
C                          THE X=0 GROUND PLANE IF IJ=1
C                          THE Y=0 GROUND PLANE IF IJ=2
C                          THE Z=0 GROUND PLANE IF IJ=3
C     I1>0
C     EITHER I1>I2>I3 OR I1>I2=0=I3
C
C  OUTPUT:
C     THE SOURCE TRIANGLE IS IMAGED ABOUT:
C     (CASE I1>0 I2=I3=0) THE I1 IMAGE PLANE.
C     (CASE I1>I2>I3=0)   THE I1 IMAGE PLANE, THEN REFLECTED
C                         ABOUT THE I2 IMAGE PLANE.
C     (CASE I1>I2>I3)     THE I1 IMAGE PLANE, THEN REFLECTED
C                         ABOUT THE I2 AND I3 IMAGE PLANES.
C     THIS NEW IMAGE TRIANGLE'S CONTRIBUTIONS TO CI ARE
C     COMPUTED AND THE RESULTS ARE ADDED TO CI
```

```
C-----------------------------------------------------------
      DIMENSION RK(3,3),RMK(3),IGNDP(3)
      COMPLEX CI,C,CPP,CMM,CII(3),CPPI,CMMI,
     &       CA(3,3),CAJ(3),CAI(3,3),CAJI(3)
      COMMON/GPLANE/NGNDP,IGNDP
      CALL BSWTCH(RK,I1.I2,I3)
      CALL FACPAR(JSF,RK,RMK)
      CALL PD3FAC(JSF,RK,RMK,CI,CAI,CAJI,IPAT)
      CALL BSWTCH(RK,I1,I2,I3)
      CALL FACPAR(JSF,RK,RMK)
      SGN=IGNDP(I1)
      IF(I2.GT.0)THEN
        SGN=SGN*IGNDP(I2)
        IF (I3.GT.0)SGN=SGN*IGNDP(I3)
      ENDIF
      C=C+SGN*CI
      DO 10 I=1,3
      DO 10 J=1,3
10      CA(I,J)=CA(I,J)+SGN*CAI(I,J)
      IF(JSF.NE.0)THEN
      DO 20 J=1,3
20      CAJ(J)=CAJ(J)+SGN*CAJI(J)
      ENDIF
      RETURN
      END
```

A.66 BSWTCH

```
C=================================================================
      SUBROUTINE BSWTCH(RK,I1,I2,I3)
C-----------------------------------------------------------------
C INPUT:
C  RK(J,I) I=1,2,3 ARE K* THE X,Y,Z COORDINATES OF THE JTH VERTEX
C      OF THE SOURCE TRIANGLE WHERE K=THE WAVE NUMBER.
C  I1>0 AND EITHER I1>I2>I3 OR I1>I2=I3=0.
C  I1,I2,I3 ARE TAKEN FROM THE SET: (0,1,2,3)
C
C OUTPUT:
C  FOR EACH VERTEX J=1,2,3 RK(J,I) IS SET TO -RK(J,I) FOR I RUNNING
C  OVER THE POSITIVE INTEGERS IN THE SET (I1,I2,I3).
C-----------------------------------------------------------------
      DIMENSION RK(3,3)
      DO 10 J=1,3
```

```
      RK(J,I1)=-RK(J,I1)
 10   CONTINUE
      IF(I2.GT.0)THEN
        DO 20 J=1,3
          RK(J,I2)=-RK(J,I2)
 20     CONTINUE
        IF(I3.GT.0)THEN
          DO 30 J=1,3
            RK(J,I3)=-RK(J,I3)
 30       CONTINUE
        ENDIF
      ENDIF
      RETURN
      END
```

A.67 FACQAD

```
C=====================================================================
      SUBROUTINE FACQAD(JSF,IQUAD,XSING,RK,RMK,RLMINK,CI,CIXSI,CIETA,
     &                  CPP,CMM,IPAT)
C---------------------------------------------------------------------
C GAUSSIAN QUADRATURE INTEGRAL OVER FACE
C INPUT:
C  IQUAD EQUALS 1,3,OR 7 THE NUMBER OF INTEGRATION POINTS.
C  XSING=0.(NO SINGULARITY EXTRACTION)  XSING=1.(SINGULARITY EXTRACTION.
C  RK(J,I) I=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE JTH VERTEX
C  OF THE SOURCE TRIANGLE.
C  RMK(I) I=1,2,3 DENOTE K* THE X,Y,Z COORDINATE OF THE MATCH POINT.
C  RLMINK=K* THE LENGTH OF THE SHORTEST SIDE OF THE SOURCE TRIANGLE.
C OUTPUT:
C  THE NORMALIZED AREA COORDINATES (XSI,ETA) AND THE NORMALIZED
C  SOURCE TRIANGLE ARE DEFINED IN TRISC.
C  DK=THE MAGNITUDE OF THE 3 DIMENSIONAL VECTOR.
C  V(I)=(1-XSI-ETA)*RK(1,I)+XSI*RK(2,I)+ETA*RK(3,I)-RMK(I) I=1,2,3.
C  CI,CIXSI,AND CIETA ARE THE INTEGRALS OVER THE NORMALIZED SOURCE
C  TRIANGLE C OF 1.,XSI,ETA (RESPECTIVELY) TIMES
C  CEXP(-I*DK)/DK D(XSI) D(ETA) WHERE I=SQRT(-1.).
C  GAUSSIAN WEIGHTS FOR THE SOURCE TRIANGLE FOR IQUAD=3,7 ARE IN STRANG
C  AND FIX, 'AN ANALYSIS OF THE FINITE ELEMENT METHOD', P.184;
C  HOWEVER, THEIR FIRST WEIGHT IS WRONG.(7PT) OURS HAS BEEN CORRECTED
C  SO THE INTEGRATION OVER A CONSTANT AND 1ST ORDER POLY IN ETA OR
C  XSI IS EXACT.
C---------------------------------------------------------------------
```

```
      IMPLICIT COMPLEX (C)
      DIMENSION RK(3,3),RMK(3),XSI3(3),XSI7(7),ETA3(3),ETA7(7)
     $     ,WGHT7(7),CFP(3),CFM(3),CSP1(3),CSM1(3),CFP1(3),CFM1(3)
      DATA XSI1,ETA1,WGHT1/.333333333333333,.333333333333333,.5/
      DATA XSI3/.666666666666667,.166666666666667,.166666666666667/
      DATA ETA3/.166666666666667,.666666666666667,.166666666666667/
      DATA WGHT3/.166666666666667/
      DATA XSI7/.333333333333333,.797426985353087,.101286507323456,
     1 .101286507323456,.470142064105115,.470142064105115,
     2 .059715871789770/
      DATA ETA7/.333333333333333,.101286507323456,.797426985353087,
     1 .101286507323456,.470142064105115,.059715871789770,
     2 .470142064105115/
      DATA WGHT7/.1125,.062969590272413,.062969590272413,
     1 .062969590272413,.066197076394253,.066197076394253,
     2  .066197076394253/
      RLIMIT=1.E-5*RLMINK
      IF(IQUAD.EQ.1)THEN
      CALL INTGRN(JSF,RK,RMK,RLIMIT,XSING,XSI1,ETA1,
     &            WGHT1,CI,CIXSI,CIETA,CFP,CFM,CSP1,CSM1,IPAT)
      ELSE
      IF(JSF.NE.0)THEN
      DO 5 J=1,3
      CFP1(J)=(0.,0.)
      CFM1(J)=(0.,0.)
      CFP(J)=(0.,0.)
5      CFM(J)=(0.,0.)
      ENDIF
        CI=(0.,0.)
        CIXSI=(0.,0.)
        CIETA=(0.,0.)
        IF(IQUAD.EQ.3)THEN
          DO 10 I=1,3
       CALL INTGRN(JSF,RK,RMK,RLIMIT,XSING,XSI3(I),ETA3(I),
     &         WGHT3,CC,CCXSI,CCETA,CFP1,CFM1,CSP1,CSM1,IPAT)
      IF(JSF.NE.0)THEN
      DO 15 J=1,3
      CFP(J)=CFP(J)+CFP1(J)
15      CFM(J)=CFM(J)+CFM1(J)
      ENDIF
            CI=CI+CC
            CIXSI=CIXSI+CCXSI
            CIETA=CIETA+CCETA
10        CONTINUE
        ELSE
```

```
          DO 20 I=1,7
          CALL INTGRN(JSF,RK,RMK,RLIMIT,XSING,XSI7(I),ETA7(I),
     &            WGHT7(I),CC,CCXSI,CCETA,CFP1,CFM1,CSP1,CSM1,IPAT)
      IF(JSF.NE.0)THEN
      DO 25 J=1,3
      CFP(J)=CFP(J)+CFP1(J)
25      CFM(J)=CFM(J)+CFM1(J)
      ENDIF
            CI=CI+CC
            CIXSI=CIXSI+CCXSI
            CIETA=CIETA+CCETA
 20       CONTINUE
        ENDIF
      ENDIF
      IF(JSF.NE.0)THEN
      CPP=CFP(JSF)+CSP1(JSF)
      CMM=CFM(JSF)+CSM1(JSF)
      ENDIF
      RETURN
      END
```

A.68 INTGRN

```
C=================================================================
      SUBROUTINE INTGRN(JSF,RK,RMK,RLIMIT,XSING,XSI,ETA,WGHT,CC,
     &                 CCXSI,CCETA,CFP,CFM,CSP1,CSM1,IPAT)
C-----------------------------------------------------------------
C INTEGRAND OF POTENTIAL INTEGRAL
C INPUT:
C  RK(J,I) I=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE JTH VERTEX
C  OF THE SOURCE TRIANGLE.
C  RMK(I) I=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE MATCH POINT.
C  RLIMIT=A SMALL CONSTANT * K* THE LENGTH OF THE SOURCE TRIANGLE'S
C  SHORTEST SIDE.
C  XSING=0. NO SINGULARITY EXTRACTION.
C  XSING=1. SINGULARITY EXTRACTION.
C  XSING MUST BE 1. IF MATCH POINT IS ON THE SOURCE TRIANGLE.
C  XSI,ETA ARE NORMALIZED AREA COORDINATES OF THE SOURCE TRIANGLE.
C  WGHT IS A WEIGHT FACTOR.
C OUTPUT:
C  CC,CCXSI,CCETA= WGHT*(CEXP(-I*DK)-XSING)/DK *(1,XSI,ETA,RESPECTIVELY)
C  WHERE I=SQRT(-1.).
C  DK=THE MAGNITUDE OF THE VECTOR.
```

```
C  VX=(1-XSI-ETA)*RK(1,1)+XSI*RK(2,1)+ETA*RK(3,1)-RMK(1)
C  VY=(1-XSI-ETA)*RK(1,2)+XSI*RK(2,2)+ETA*RK(3,2)-RMK(2)
C  VZ=(1-XSI-ETA)*RK(1,3)+XSI*RK(2,3)+ETA*RK(3,3)-RMK(3)
C---------------------------------------------------------------
      IMPLICIT COMPLEX (C)
      DIMENSION RK(3,3),RMK(3),V(3),CFP(3),CFM(3),CSP1(3),CSM1(3)
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      ZETA=1.-XSI-ETA
        IF(IPAT.GT.0)THEN
        DO 2 J=1,3
2       V(J)=-(ZETA*RK(1,J)+XSI*RK(2,J)+ETA*RK(3,J))
        DK=V(1)*RMK(1)+V(2)*RMK(2)+V(3)*RMK(3)
        ELSE
        DO 3 J=1,3
3       V(J)=RMK(J)-(ZETA*RK(1,J)+XSI*RK(2,J)+ETA*RK(3,J))
        DK=SIZE(V(1),V(2),V(3))
        ENDIF
        C=CMPLX(0.,-DK)
        CDK=CEXP(C)
        IF(IPAT.GT.0)THEN
        CE=WGHT*CDK
      ELSEIF(DK.GT RLIMIT)THEN
        CE=WGHT*(CDK-XSING)/DK
      ELSEIF(XSING.EQ.1.)THEN
        CE=(0.,-1.)*WGHT
      ELSE
        WRITE(4,99)
 99     FORMAT(1X,'WARNING IN QUAD SINGULARITY WITH NO EXTRACTION'
        STOP
      ENDIF
C
C IF THERE ARE ANY JUNCTIONS, CALL INTJUN TO COMPUTE INTEGRATION DUE TO
C JUNCTION BASIS FUNCTION
C
      IF(JSF.NE.0.)THEN
        IF(IPAT.EQ.0)THEN
C
      CALL INTJUN(JSF,RK,RMK,V,DK,CDK,XSING,XSI,ETA,WGHT,
     &                  CFP,CFM,CSP1,CSM1,IPAT)
        ELSE
C COMPUTE VECTOR POTENTIAL FOR FAR FIELD
      CALL JKFPAT(JSF,RK,RMK,CDK,XSING,XSI,ETA,WGHT,
     &                CFP,CFM,CSP1,CSM1)
C
      ENDIF
```

```
      ENDIF
      CC=CE
      CCXSI=CE*XSI
      CCETA=CE*ETA
      RETURN
      END
```

A.69 PS3FAC

```
C=====================================================================
      SUBROUTINE PS3FAC(JSF,R,SINGT,SP2,SM2)
C---------------------------------------------------------------------
C POTENTIAL INTEGRAL OF SCALAR 3-D GREEN'S FUNCTION OVER FACE
C INPUT:
C  EACH VECTOR SAY V,V(I) I=1,2,3 CORRESPONDS TO THE X,Y,AND Z
C  COMPONENTS OF V RESPECTIVELY.
C  R(J,I) J=1,2,3 CORRESPONDS TO VECTORS FROM THE ORIGIN TO THE
C  1,2,3 VERTICIES RESPECTIVELY OF THE SOURCE TRIANGLE.
C  RM IS THE VECTOR FROM THE ORIGIN TO THE MATCH POINT.
C  RMO IS THE PROJECTION OF RM INTO THE PLANE OF THE SOURCE TRIANGLE.
C  UN IS THE UNIT NORMAL TO THE PLANE OF THE SOURCE TRIANGLE.
C  IT IS DETERMINED BY THE RIGHT HAND RULE APPLIED TO VERTICIES 1,2,3.
C  DPERP IS THE DISTANCE OF RM TO RMO (DPERP.GE.0).
C OUTPUT:
C  SING=THE INTEGRAL OVER THE SOURCE TRIANGLE OF
C  1./ABS(VECTOR(RP-RM)) D(AREAP).
C  SINGV(I) I=1,2,3 = THE X,Y,Z COMPONENTS OF THE INTEGRAL OVER THE
C  SOURCE TRIANGLE OF  VECTOR(RP-RMO)/ABS(VECTOR(RM-RP)) D(AREAP).
C  RP=THE SOURCE VECTOR LOCATION.
C  REFERENCE:'POTENTIAL INTEGRALS FOR UNIFORM AND LINEAR SOURCE
C  DISTRIBUTIONS IN POLYHEDRAL DOMAINS'
C  D.R.WILTON ET. AL. TO APPEAR IN IEEE. AP MARCH 1984.
C  SING=THE SUM OVER THE SOURCE TRIANGLE EDGES OF:
C      (PO)HAT DOT (UU)HAT [PO*LN((RRP+ALP)/(RRM+ALM))
C      -D*(ATAN(PO*ALP/(PO**2+D**2+D*RRP))-ATAN(PO*ALM/(PO**2+D**2+D*
C  RRM)))]
C  SINGV(I)(I=1,2,3)=THE X,Y,Z COMPONENTS OF THE SUM OVER THE EDGES
C  OF THE SOURCE TRIANGLE OF
C  .5*(UU)HAT *[(D**2+PO**2)*LN((RRP+ALP)/(RRM+ALM))+ALP*RRP-ALM*RRM]
C  PO=THE PERPENDICULAR DISTANCE FROM RMO TO THE EDGE OF THE
C     SOURCE TRIANGLE.
C  (PO)HAT IS THE UNIT VECTOR THAT POINTS FROM RMO TOWARDS THE EDGE.
C  (UU)HAT IS THE OUTWARD POINTING UNIT NORMAL OF THE SOURCE TRIANGLE
```

```
C  THAT LIES IN THE PLANE OF THE SOURCE TRINAGLE.
C  D=DPERP.
C  ALP=THE DIRECTED DISTANCE BETWEEN THE PROJECTION OF RM ONTO THE
C  EDGE AND THE (PLUS)VERTEX.
C  ALM=THE DIRECTED DISTANCE BETWEEN THE PROJECTION OF RM ONTO THE
C  EDGE AND THE (MINUS) VERTEX.
C  FOR AN EDGE RUNNING FROM VERTEX IVTX TO VERTEX IVTX1,
C  THE PLUS VERTEX IS IVTX1 AND THE MINUS VERTEX IS IVTX.
C  RRP=SQRT(D**2+PO**2+ALP**2).
C  RRM=SQRT(D**2+PO**2+ALM**2).
C-------------------------------------------------------------
      IMPLICIT COMPLEX (C)
C
      DIMENSION R(3,3),RMO(3),UN(3),SINGV(3),UL(3,3),UH(3,3),RI(3,3)
     $,H(3),SINGT(3),VPO(3,3),VH(3,3),DL(3,3),AL(3),P(3,3),SXI(3)
     $                  ,PH(3),RR2(3),RR(3),SP2(3),SM2(3),HPS(3)
      COMMON/JUN/RI,P,PH,RR,RR2,RIL,URI,VH
      COMMON/S2/HPR,HMR
      COMMON/CONJ/XSING2
      COMMON/FARA/DL,DET,H,AL,UL,UH,RM,UN,DDPERP
      DPERP=DDPERP
      ISH=JSF
      SING=0.
      DO 2 J=1,3
2      SINGV(J)=0.
      DO 10 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
        PO=UH(I,1)*(R(IP1,1)-RMO(1))+UH(I,2)*(R(IP1,2)-RMO(2))
     $            +UH(I,3)*(R(IP1,3)-RMO(3))
      DO 4 J=1,3
4      VPO(I,J)=PO*UH(I,J)
        SGN=1.
        IF(PO.LT.0.)THEN
          SGN=-1.
          PO=-PO
        ENDIF
        ALP=UL(I,1)*(R(IM1,1)-RMO(1))+UL(I,2)*(R(IM1,2)-RMO(2))
     $            +UL(I,3)*(R(IM1,3)-RMO(3))
        ALM=UL(I,1)*(R(IP1,1)-RMO(1))+UL(I,2)*(R(IP1,2)-RMO(2))
     $            +UL(I,3)*(R(IP1,3)-RMO(3))
C
        CALL CAS(PO,DPERP,ALP,ALM,VALA,VALL)
C
        SING=SING+SGN*VALA
```

```
      DO 6 J=1,3
6        SINGV(J)=SINGV(J)+UH(I,J)*VALL
 10   CONTINUE
C
C
      DO 8 I=1,3
      HPS(I)=0.
      DO 9 J=1,3
9      HPS(I)=HPS(I)+(UH(I,J)*(VPO(I,J)*SING-SINGV(J)))
8      SINGT(I)=HPS(I)/DET/H(I)
C
C THE INTEGRATION OF THE TAYLOR SERIES EXPANSION OF THE INTEGRAND
C OF THE JUNCTION POTENTIAL INTEGRATION AT THE JUNCTION VERTEX
C SINGULARITY
C
C UHS= UNIT VET H DOT VET IO
C SINGV(J)= VET IO = INTEGRAL OF
C
      IF(JSF.NE.0.AND.XSING2.NE.1.) THEN
      I=JSF
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
      SXI(IP1)=HPS(IP1)/H(IP1)
      SXI(IM1)=HPS(IM1)/H(IM1)
      HLP=0.
      HLM=0.
      DO 24 J=1,3
      HLP=HLP+UH(I,J)*DL(IP1,J)
      HLM=HLM+UH(I,J)*DL(IM1,J)
24      CONTINUE
      SX=2./RR(I)*(RR(I)*SING-HLM*SXI(IP1)+HLP*SXI(IM1))
      RCON=1./RR2(I)/DET
      SP2(I)=RCON*(SXI(IP1)-HPR*SX)
      SM2(I)=RCON*(SXI(IM1)-HMR*SX)
      ELSE
        DO 30 II=1,3
        SP2(II)=0.
30      SM2(II)=0.
      ENDIF
      RETURN
      END
```

A.70 CAS

```
C==============================================================
      SUBROUTINE CAS(PO,DPERP,ALP,ALM,VALA,VALL)
C--------------------------------------------------------------
C . . .CONSTANTS -- RRO IS DIST. TO LINE? RRP AND RRM, TO VERTICES . . .
C INPUT:
C  PO=THE PERPENDICULAR DISTANCE FROM RMO TO THE EDGE OF THE SOURCE
C  TRIANGLE UNDER CONSIDERATION. DPERT IS THE PERPENDICULAR DISTANCE OF
C  RRM TO RMO AS DEFINED IN ISING. ALP IS THE DIRECTED DISTANCE FROM
C  THE PROJECTION OF RRM ONTO THE EDGE OF THE SOURCE TRIANGLE.
C  VALA=[PO*LN(RRP+ALP)/(RRM+ALM))
C       -DPERP*(ATAN(PO*ALP/(PO**2+DPERP**2+DPERP*RRP)
C       -ATAN(PO*ALM/(PO**2+DPERP**2+DPERP*RRM)))]
C  CVALL=.5*[(DPERP**2+PO**2)*LN((RRP+ALP)/(RRM+ALP))+ALP*RRP-ALM*RRM]
C  THE NOTATION IN THIS ROUTINE IS THE SAME AS IN CALLING ROUTINE ISING.
C--------------------------------------------------------------
      RROSQ=DPERP*DPERP+PO*PO
      RRO=SQRT(RROSQ)
      RRP=SQRT(RROSQ+ALP*ALP)
      RRM=SQRT(RROSQ+ALM*ALM)
      AL=ALP-ALM
      RATIO=RRO/AL
      IF(RATIO .GT. 1E-4) THEN
        PERPD=ABS(DPERP)
        ALGTRM=ALOG( (RRP+ALP)/(RRM+ALM))
        ARGTNP=PO*ALP/(RROSQ+PERPD*RRP)
        ARGTNM=PO*ALM/(RROSQ+PERPD*RRM)
        VALA=PO*ALGTRM-PERPD*(ATAN(ARGTNP)-ATAN(ARGTNM))
        VALL=.5*(RROSQ*ALGTRM+ALP*RRP-ALM*RRM)
      ELSE
        VALA=0.
        VALL=.5*(ALP*RRP-ALM*RRM)
      ENDIF
      RETURN
      END
```

A.71 JKFPAT

```
C==============================================================
      SUBROUTINE JKFPAT(JSF,RK,RMK,CDK,XSING,XSI,ETA,WGHT,
     &                  CFP,CFM,CSP,CSM)
C--------------------------------------------------------------
```

```
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR POTENTIAL
C ASSOCIATE WITH JUNCTION BASIS FUNCTION BY USING FAR FIELD KERNEL
C RK(I,J) J=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE ITH VERTEX OF
C THE SOURCE TRIANGLE. (K=THE WAVE NUMBER)
C RMK(I) I=1,2,3 DENOTES THE X,Y,Z COORDINATES OF THE MATCH POINT.
C H(I) IS THE LENGTH OF THE HEIGHT VECTOR.
C DL(I,J) IS THE VECTOR FROM THE I+1TH VERTEX TO THE ITH VERTEX.
C-----------------------------------------------------------------
      IMPLICIT COMPLEX (C)
      DIMENSION RK(3,3),RMK(3),XI(3),RI(3,3),H(3),
     &DL(3,3),CFP(3),CFM(3),CSP(3),CSM(3)
      COMMON/JUN/RI
      COMMON/PARA/DL,DET,H
      CRX(X)=CMPLX(X,0.)
      CIX(X)=CMPLX(0.,X)
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      ZETA=1.-XSI-ETA
      XI(1)=ZETA
      XI(2)=XSI
      XI(3)=ETA
      DO 20 I=1,3
      CFP(I)=(0.,0.)
20    CFM(I)=(0.,0.)
      I=JSF
C     DO 10 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
C HS2=(H(I)*(1-XI(I))**2
C
        RRI=0.
        DO 30 J=1,3
30      RRI=RRI+RMK(J)*RI(I,J)
        HS=H(I)*(1.-XI(I))
        HS2=HS*HS
C
      CF=1./HS2*(CDK-CRR)
      CFP(I)=XI(IP1)*CF*WGHT
      CFM(I)=XI(IM1)*CF*WGHT
C
C CDK=EXP(-JR)
C
C THE INTEGRATION OF THE TAYLOR SERIES EXPANSION OF THE INTEGRAND
C AT THE JUNCTION VERTEX SINGULARITY
C
      CSP(I)=1./H(I)/H(I)*CRR*0.5
```

```
      CSM(I)=CSP(I)
10    CONTINUE
      RETURN
```

A.72 INTJUN

```
C=====================================================================
      SUBROUTINE INTJUN(JSF,RK,RMK,V,DK,CDK,XSING,XSI,ETA,WGHT,
     &                 CFP,CFM,CSP1,CSM1,IPAT)
C---------------------------------------------------------------------
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C ASSOCIATE WITH JUNCTION BASIS FUNCTION
C RK(I,J) J=1,2,3 DENOTES K* THE X,Y,Z COORDINATES OF THE ITH VERTEX OF
C THE SOURCE TRIANGLE. (K=THE WAVE NUMBER)
C RMK(I) I=1,2,3 DENOTES THE X,Y,Z COORDINATES OF THE MATCH POINT.
C UN(I) I=1,2,3 DENOTES THE X,Y,Z COORDINATES OF THE UNIT NORMAL VECTOR
C TO THE PLANE OF THE SOURCE TRIANGLE.
C UL(I,J) IS THE UNIT VECTOR FROM THE I+1TH VERTEX TO THE ITH VERTEX
C UH(I,J) IS THE UNIT HEIGHT VECTOR WHICH NORMAL TO UL(I,J).
C UH = UL X UN
C H(I) IS THE LENGTH OF THE HEIGHT VECTOR.
C DL(I,J) IS THE VECTOR FROM THE I+1TH VERTEX TO THE ITH VERTEX.
C AL(I) IS THE LENGTH OF THE DL(I,J)
C RMKO= THE PROJECTION OF RMK ONTO THE PLANE OF THE SOURCE TRIANGLE
C DPERPK= K* THE PERPENDICULAR DISTANCE FROM THE MATCH POINT TO THE
C PLANE OF THE TRIANGLES
C---------------------------------------------------------------------
      IMPLICIT COMPLEX (C)
      DIMENSION RK(3,3),RMK(3),V(3),XI(3),UV(3),RI(3,3),URI(3,3),
     &AL(3),UL(3,3),UH(3,3),H(3),P(3,3),VH(3,3),CT(3),CS(3),
     &DL(3,3),RMKO(3),PH(3),RR(3),RR2(3),CFP(3),CFM(3),RIL(3),VR(3),
     &CSP1(3),CSM1(3)
      COMMON/CONJ/XSING2
      COMMON/S2/HPR,HMR
      COMMON/JUN/RI,P,PH,RR,RR2,RIL,URI,VH
      COMMON/PARA/DL,DET,H,AL,UL,UH,RMKO
      CRX(X)=CMPLX(X,0.)
      CIX(X)=CMPLX(0.,X)
      SIZE(X,Y,Z)=SQRT(X*X+Y*Y+Z*Z)
      ZETA=1.-XSI-ETA
      XI(1)=ZETA
      XI(2)=XSI
      XI(3)=ETA
```

```
      DO 20 I=1,3
      CFP(I)=(0.,0.)
20    CFM(I)=(0.,0.)
      I=JSF
C     DO 10 I=1,3
      IP1=MOD(I,3)+1
      IM1=MOD(I+1,3)+1
C
C RI(I,J) ARE THE VECTOR FROM THE MATCH POINT TO THE ITH VERTEX
C OF THE SOURCE TRIANGLE.
C RIL IS THE LENGTH OF RI
C URI(I,J) ARE THE UNIT VECTOR OF RI(I,J)
C RIH= UNIT VECTOR OF RI DOT UNIT VECTOR OF HEIGHT
C RR(I)= RI*(UNIT VET RI DOT UNIT VET H)
C
C DRP= VET L(I+1) DOT UNIT VET RI
C DRM= VET L(I-1) DOT UNIT VET RI
C HS2=(H(I)*(1-XI(I))**2
C
      DRP=0.
      DRM=0.
      DO 30 J=1,3
      DRP=DRP+DL(IP1,J)*URI(I,J)
30    DRM=DRM+DL(IM1,J)*URI(I,J)
      HS=H(I)*(1.-XI(I))
      HS2=HS*HS
C
C CRK=EXP(-JRI)/RI
C CR2=(1+JRI)/RI
C
      CRK=CEXP(CIX(-RIL(I)))/RIL(I)
      CR2=(CRX(1.)+CIX(RIL(I)))/RIL(I)
      WH=WGHT
C
C CDK=EXP(-JR)
C CF IS THE FIRST TERM OF THE NUMERICAL INTEGRAL OF THE POTENTIAL
C INTEGRAL EQUATION
C
      RATIO=DK/AL(I)
C
C IF R=0 TAKE THE LIMIT VALUE OF THE INTEGRAL FUNCTION
C TO AVOID OVERFLOW
C
      XDK=0.
      IF(DK.LT.1.E-7) THEN
```

```
      CF=-1./HS2*(CIX(1.)+CRK*(CRX(1.)+CR2*RIL(I)))
C
C TAKE LIMIT OF
C THE WHOLE NUMERICAL INTEGRAL AT R=0
C
      XDK=1.
C
C SET FLAG TO SKIP NUMERICAL INTEGRAL AT THE SINGULALITY R=0
C
      ELSE
C
C NUMERICAL INTEGRAL IN WHICH THE TAYLOR SERIES EXPANSION OF THE
C INTEGRAND AT THE JUNCTION VERTEX SINGULARITY HAS BEEN SUBTRACTED
C
      CF=1./HS2*(CDK/DK-CRK*(CRX(1.)+CR2*(XI(IP1)*DRM-XI(IM1)*DRP)))
      ENDIF
C
C NOTE: ONLY COMPUTE ONCE FOR EACH JUNCTION PATCH
C
      H2=H(I)*H(I)
      CON=CRK/H2*.5
C
C THE INTEGRATION OF THE TAYLOR SERIES EXPANSION OF THE INTEGRAND
C AT THE JUNCTION VERTEX SINGULARITY
C
      CRP(I)=CON*(CRX(1.)+CR2*(DRM/3.-[illegible]
      CRM(I)=CON*(CRX(1.)+CR2*(DRM/6.-[illegible]
C
      IF(XDK.EQ.1. .OR.XSING.NE.1.[illegible] THEN
C
C CFP,CFM ARE THE NUMERICAL INTEGRATION
C IN WHICH THE SINGULARITY AT VERTEX HAS BE SUBTRACTED OUT
C
      CFP(I)=XI(IP1)*CF*WH
      CFM(I)=XI(IM1)*CF*WH
      ELSE
C
C V IS THE VECTOR FROM THE MATCH POINT TO THE SOURCE POINT
C DK IS THE LENGTH OF V
C P(I,J) IS THE PROJECTION OF VECTOR RI IN THE SOURCE TRIANGLE PLANE
C PH(I)= VET PI DOT UNIT VECTOR OF HEIGHT
C RIH= UNIT VECTOR OF RI DOT UNIT VECTOR OF HEIGHT
C HR= UNIT VECTOR OF HEIGHT DOT UNIT VECTOR OF R
C
      HLP=0.
```

AD-A200 315 JUNCTION CODE USER'S MANUAL ELECTROMAGNETIC SCATTERING AND RADIATION BY A..(U) HOUSTON UNIV ELECTROMAGNETICS LAB D R WILTON ET AL. AUG 88 TR-87-18 NOSC-TD-1324 3/3

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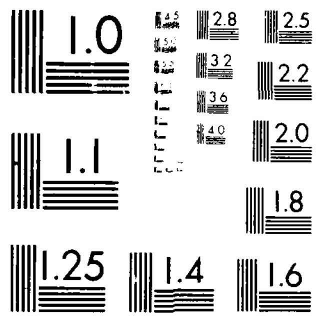

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
      HLM=0.
      HPR=0.
      HMR=0.
      GPM=0.
      DO 70 J=1,3
      GPM=GPM+UH(I,J)*V(J)
      HPR=HPR+UH(IP1,J)*RI(I,J)
70    HMR=HMR+UH(IM1,J)*RI(I,J)
      HPR=HPR/H(IP1)
      HMR=HMR/H(IM1)
C
C RR(I)= RI*(UNIT VET RI DOT UNIT VET H)
C
      GPM=2./RR(I)*GPM
      YP=HPR*GPM
      YM=HMR*GPM
      GP=(XI(IP1)-YP)/RR2(I)/DK
      GM=(XI(IM1)-YM)/RR2(I)/DK
      C1=XI(IP1)*CF
      C2=XI(IM1)*CF
C
C CFP,CFM ARE THE NUMERICAL INTEGRATIONS
C IN WHICH THE SINGULARITIES AT JUNCTION VERTEX AND R=.
C HAVE BE SUBTRACTED OUT
C
      CFP(I)=(C1-CRX(GP))*WH
      CFM(I)=(C2-CRX(GM))*WH
      ENDIF
10    CONTINUE
      RETURN
      END
      END
```

A.73 POTWIR

```
C=====================================================================
      SUBROUTINE POTWIR(SSPOT,VAP,VAM,IPAT)
C---------------------------------------------------------------------
C POTENTIAL INTEGRAL OVER WIRE SEGMENT
C     INPUT:
C  RSK(J) ARE K* THE X,Y,Z COORDINATES OF THE CENTER POINT
C     OF THE SOURCE SEGMENT WHERE K=THE WAVE NUMBER.
C     RMK(I) I=1,2,3 DENOTE THE X,Y,Z COORDINATES OF THE MATCH POINT.
```

```
C      CONSTANTS PASSED THROUGH COMMON/GPLANE/
C      NGNDP=0,1,2,OR 3 THE NUMBER OF WIMAGE PLANES.
C       IGNDP(I)=0  NO GROUND PLANES;
C               -1 A P.E.C. GROUND PLANE;
C                1 A P.M.C. GROUND PLANE.
C                I=1,2,3 DENOTES THE X=0,Y=0,ANDZ=0 GROUND PLANES.
C       OUTPUT:
C      SSPOT: SCALAR POTENTIAL
C      VAP,VAM: VECTOR POTENTIALS
C-------------------------------------------------------------------
       COMPLEX  CSPW,VAP(3),VAM(3),SSPOT
       INTEGER IGNDP(3)
       COMMON/GPLANE/NGNDP,IGNDP
       CALL PDWSEG(SSPOT,VAP,VAM,IPAT)
        IF(NGNDP.GT.0)THEN
         DO 20 I=1,3
           IF(IGNDP(I).NE.0)CALL WIMAGE(SSPOT,VAP,VAM,I
      $             ,0,0,IPAT)
 20      CONTINUE
         IF(NGNDP.GE.2)THEN
           IF(IGNDP(1).EQ.0)THEN
             CALL WIMAGE(SSPOT,VAP,VAM,3,2,0,IPAT)
           ELSEIF(IGNDP(2).EQ.0)THEN
             CALL WIMAGE(SSPOT,VAP,VAM,3,1,0,IPAT)
           ELSE
             CALL WIMAGE(SSPOT,VAP,VAM,2,1,0,IPAT)
             IF(IGNDP(3).NE.0)THEN
               CALL WIMAGE(SSPOT,VAP,VAM,3,2,0,IPAT)
               CALL WIMAGE(SSPOT,VAP,VAM,3,1,0,IPAT)
             ENDIF
           ENDIF
           IF(NGNDP.GE.3)CALL WIMAGE(SSPOT,VAP,VAM,3,2,1,IPAT)
         ENDIF
       ENDIF
       RETURN
       END
```

A.74 WIMAGE

```
C====================================================================
       SUBROUTINE WIMAGE(SSPOT,VAP,VAM,I1,I2,I3,IPAT)
C-------------------------------------------------------------------
C  INPUT:
```

```
C  RSK(J) ARE K* THE X,Y,Z COORDINATES OF THE CENTER POINT
C     OF THE SOURCE SEGMENT WHERE K=THE WAVE NUMBER.
C     RMK(I) I=1,2,3 DENOTE K* THE X,Y,Z COORDINATES OF THE MATCH POINT.
C     IJ J=1,2,3 DENOTES : 0 IMAGE PLANES IF IJ=0
C                          THE X=0 GROUND PLANE IF IJ=1
C                          THE Y=0 GROUND PLANE IF IJ=2
C                          THE Z=0 GROUND PLANE IF IJ=3
C     I1>0
C     EITHER I1>I2>I3 OR I1>I2=0=I3
C
C  OUTPUT:
C     THE SOURCE SEGMENT IS IMAGED ABOUT:
C     (CASE I1>0 I2=I3=0) THE I1 IMAGE PLANE
C     (CASE I1>I2>I3=0)   THE I1 IMAGE PLANE, THEN REFLECTED
C                         ABOUT THE I2 IMAGE PLANE.
C     (CASE I1>I2>I3)     THE I1 IMAGE PLANE, THEN REFLECTED
C                         ABOUT THE I2 AND I3 IMAGE PLANES.
C     THIS NEW IMAGE SEGMENT'S CONTRIBUTIONS TO POTENTIALS ARE
C     COMPUTED AND THE RESULTS ARE ADDED TO THEM
C-----------------------------------------------------------
      COMPLEX  CSPW,VAP(3),VAM(3),SSPOT,VAPI(3),VAMI(3),SSPOTI
      INTEGER IGNDP(3)
      COMMON/GPLANE/NGNDP,IGNDP
      CALL WSWTCH(I1,I2,I3)
      CALL PDWSEG(SSPOTI,VAPI,VAMI,IPAT)
      CALL WSWTCH(I1,I2,I3)
      SGN=IGNDP(I1)
      IF(I2.GT.0)THEN
        SGN=SGN*IGNDP(I2)
        IF (I3.GT.0)SGN=SGN*IGNDP(I3)
      ENDIF
            DO 5 J=1,3
        VAP(J)=SGN*VAPI(J)+VAP(J)
        VAM(J)=SGN*VAMI(J)+VAM(J)
 5    CONTINUE
        SSPOT=SGN*SSPOTI+SSPOT
      RETURN
      END
```

A.75 WSWTCH

```
C============================================================
      SUBROUTINE WSWTCH(I1,I2,I3)
```

```
C-----------------------------------------------------------------------
C INPUT:
C  RSK(J) ARE K* THE X,Y,Z COORDINATES OF THE CENTER POINT
C      OF THE SOURCE SEGMENT WHERE K=THE WAVE NUMBER.
C  SH(j) ARE K* THE X,Y,Z COORDINATES OF THE UNIT VECTOR
C      OF THE SOURCE SEGMENT WHERE K=THE WAVE NUMBER.
C  I1>0 AND EITHER I1>I2>I3 OR I1>I2=I3=0.
C  I1,I2,I3 ARE TAKEN FROM THE SET: (0,1,2,3)
C
C OUTPUT:
C  FOR J=1,2,3 RSK(J) IS SET TO -RSK(J) FOR I RUNNING
C  OVER THE POSITIVE INTEGERS IN THE SET (I1,I2,I3).
C-----------------------------------------------------------------------
      DIMENSION SH(3),RSK(3),RMK(3)
      COMMON/WKERNL/RSK,SH,RMK,RADSK,RADSKS
      RSK(I1)=-RSK(I1)
      SH(I1)=-SH(I1)
      IF(I2.GT.O)THEN
          RSK(I2)=-RSK(I2)
      SH(I2)=-SH(I2)
        IF(I3.GT.O)THEN
            RSK(I3)=-RSK(I3)
      SH(I3)=-SH(I3)
        ENDIF
      ENDIF
      RETURN
      END
```

A.76 PDWSEG

```
C=======================================================================
      SUBROUTINE PDWSEG(SSPOT,VAP,VAM,IPAT)
C-----------------------------------------------------------------------
C POTENTIAL INTEGRAL OF DYNAMIC WIRE GREEN'S FUNCTION OVER SEGMENT
      COMPLEX  VAP(3),VAM(3),SSPOT,CSPW,ANS(3)
     >         ,CKRED,CKTOT,CKSELF,CANS,CPATT
      DIMENSION IGNDP(3),RMK(3),SH(3),RSK(3)
      REAL LAMBDA,K,MU,IMP
      COMMON/MEDIUM/DEG2RAD,EPSLON,MU,IMP,SL,PI
      COMMON/POT/NM,NS,DEL,DELS,DELH,DELRH,RVPW,CSPW,RADMKK
      COMMON/WAVE/OMEGA,LAMBDA,K
      COMMON/WKERNL/RSK,SH,RMK,RADSK,RADSKS
      COMMON/WKER/DPAR,RHO,RHOPR,RHOPRS,RHOMRS
```

```
      COMMON/WIRE/IQUADW
      COMMON/WIRSLF/IQWS
      COMMON/GPLANE/NGNDP,IGNDP
      EXTERNAL CKRED,CKTOT,CKSELF,CPATT
      IQUAD=IQUADW
      IQUAWS=IQWS
      DELI=DEL
      RADMKS=RADMKK
C
* COMPUTE QUANTITIES FOR CALCULATION OF THE VECTOR AND SCALAR POTENTIALS
C
        IF(IPAT.GT.0)THEN
        ROS=100.
        IQUAD=4
              CALL SEGQAD(CPATT,DELI,IQUAD,ANS)
        ELSE
            ROS=(RSK(1)-RMK(1))**2+(RSK(2)-RMK(2))**2+(RSK(3)-RMK(3))**2
            IF(IPAT.EQ.0.AND.ROS.LE.3.9*DELS)THEN
C
* SINGULAR TERM TREATED ANALYTICALLY.
C
              DPAR=(RSK(1)-RMK(1))*SH(1)+(RSK(2)-RMK(2))*SH(2)+
     >             (RSK(3)-RMK(3))*SH(3)
              DPERPS=ROS-DPAR*DPAR
              RHO=SQRT(DPERPS+RADMKS)
              RHOPR=RHO+RADSK
              RHOMR=RHO-RADSK
              RHOPRS=RHOPR*RHOPR
              RHOMRS=RHOMR*RHOMR
              IF(NM.EQ.NS)THEN
                  DELRHI=DELRH
                  DELHI=DELH
                IF(DELH.GT.DELRH)THEN
                  CALL SGQADS(CKTOT,DELRHI,DELHI,IQUAWS,CANS)
                  ANS(1)=CANS
                  XU=DELRHI
                ELSE
                  XU=DELHI
                  ANS(1)=(0.,0.)
                ENDIF
                CALL SGQADS(CKSELF,0.,XU,IQUAWS,CANS)
                XUS=XU*XU
            SIN1=XU*ALOG((XUS+RHOMRS)/(XUS+RHOPRS))
            IF(RHOMR.EQ.0.)THEN
            SINGT=SIN1-2.*RHOPR*ATAN(XU/RHOPR)
```

```
            ELSE
               SINGT=SIN1
     >                 +2.*(RHOMR*ATAN(XU/RHOMR)-RHOPR*ATAN(XU/RHOPR))
            ENDIF
               ANS(1)=2.*(ANS(1)+CANS-SINGT/(RHOPR*PI))
C BY SYMMETRY
               ANS(2)=.5*ANS(1)
               ANS(3)=ANS(2)
             ELSE
               CALL SEGQAD(CKTOT,DELI,IQUAD,ANS)
             ENDIF
            ELSE
             CALL SEGQAD(CHREL,DELI,IQUAD,ANS)
            ENDIF
            ENDIF
C
* FILL WIRE PORTION OF THE IMPEDANCE MATRIX
* COMPUTE VECTOR AND SCALAR POTENTIAL CONTRIBUTIONS
* DUE TO THE SOURCE SEGMENT.
C
            SSPOT=CSPW*ANS(1)/(DELI/K)
            ANS(2)=RVPW*ANS(2)
            ANS(3)=RVPW*ANS(3)
300         FORMAT(X,'AN',I4,6E11.3)
            DO 10 J=1,3
              VAP(J)=ANS(2)*SH(J)
              VAM(J)=ANS(3)*SH(J)
 10         CONTINUE
            RETURN
            END
```

A.77 CKTOT

```
C======================================================================
      COMPLEX FUNCTION CKTOT(SP)
C----------------------------------------------------------------------
* INPUT:
*  SP=K*THE DISTANCE OF THE SOURCE POINT FROM THE CENTROID OF THE SOURCE
*  SEGMENT. SP IS POSITIVE IF THE DISTANCE IS TOWARDS THE SOURCE
*  SEGMENT'S ENDPOINT AND NEGATIVE IF TOWARDS THE INITIAL POINT.
*  RADSK =K*THE SOURCE SEGMENT RADIUS.
*  RADSKS=RADSK*RADSK
*  DPAR=(RSK(1)-RMK(1))*SH(1)+(RSK(2)-RMK(2))*SH(2)+
```

```
*        (RSK(3)-RMK(3))*SH(3)
*   RHO=SQRT(DPAR**2+RADMKS),WHERE RADMKS=(K* THE RADIUS OF
*        THE MATCH SEGMENT)**2
*   RHOPRS=(RHO+RADSK)**2
*   RHOMRS=(RHO-RADSK)**2
*  OUTPUT:
*   CKTOT IS THE TOTAL KERNEL . A REDUCED KERNEL APPROXIMATION IS
*   USED FOR THE SMOOTH TERM (CEXP((0.,-R)-1.)/R).
C-------------------------------------------------------------------
      DIMENSION RMK(3),SH(3),RSK(3)
      COMPLEX CBNDR
      COMMON /WKERNL/RSK,SH,RMK,RADSK ,RADSKS
      COMMON/WKER/DPAR,RHO,RHOPR,RHOPRS,RHOMRS
      DATA PIDTWO /1.570796326794897/
C
      SPS=(RSK(1)+SP*SH(1)-RMK(1))**2+(RSK(2)+SP*SH(2)-RMK(2))**2
     >          +(RSK(3)+SP*SH(3)-RMK(3))**2
      R=SQRT(SPS+RADSKS)
C
* CBNDR IS THAT PORTION OF THE KERNEL TO WHICH THE REDUCED KERNEL
* APPROXIMATION IS APPLIED.
C
       CBNDR=(CEXP(CMPLX(0.,-R))-1.)/R
      TERM=(SP+DPAR)**2
      DENOMS=TERM+RHOPRS
      DENOM=SQRT(DENOMS)
      BETA1=(TERM+RHOMRS)/DENOMS
      ELIPT=ELIC1K(BETA1)/(DENOM*PIDTWO)
      CKTOT=CBNDR+ELIPT
      RETURN
      END
```

A.78 CKSELF

```
C===================================================================
      COMPLEX FUNCTION CKSELF(SP)
C-------------------------------------------------------------------
* INPUT:
*   SP=K*THE DISTANCE OF THE SOURCE POINT FROM THE CENTROID OF THE SOURCE
*   SEGMENT. SP IS POSITIVE IF THE DISTANCE IS TOWARDS THE SOURCE
*   SEGMENT'S ENDPOINT AND NEGATIVE IF TOWARDS THE INITIAL POINT.
*   RADSK =K*THE SOURCE SEGMENT RADIUS.
*   RADSKS=RADSK*RADSK
```

```
*  RHO=SQRT(DPAR**2+RADMKS),WHERE RADMKS=(K* THE RADIUS OF
*      THE MATCH SEGMENT)**2
*  RHOPRS=(RHO+RADSK)**2
*  RHOMRS=(RHO-RADSK)**2
* OUTPUT:
*  CKSELF IS THE TOTAL KERNEL  MINUS THE SINGULAR PART OF THE ELLIPTIC
*  INTEGRAL CONTRIBUTION.
* A REDUCED KERNEL  APPROXIMATION IS USED FOR THE SMOOTH
* TERM (CEXP((0.,-R)-1.)/R).
C-----------------------------------------------------------------------
      DIMENSION RMK(3),SH(3),RSK(3)
      COMPLEX CBNDR
      COMMON /WKERNL/RSK,SH,RMK,RADSK ,RADSKS
      COMMON/WKER/DPAR,RHO,RHOPR,RHOPRS,RHOMRS
      DATA PIDTWO /1.570796326794489/
C
      SPS=SP*SP
      R=SQRT(SPS+RADSKS)
C
* CBNDR IS THAT PORTION OF THE KERNEL TO WHICH THE REDUCED KERNEL
* APPROXIMATION IS APPLIED.
C
      CBNDR=(CEXP(CMPLX(0.,-R))-1.)/R
      TERM=SPS
      DENOMS=TERM+RHOPRS
      DENOM=SQRT(DENOMS)
      BETA1=(TERM+RHOMRS)/DENOMS
      ELIPT=(ELIC1K(BETA1)/DENOM+.5*ALOG(BETA1)/RHOPR)/PIDTWO
      CKSELF=CBNDR+ELIPT
      RETURN
      END
```

A.79 CKRED

```
C======================================================================
      COMPLEX FUNCTION CKRED(SP)
C----------------------------------------------------------------------
* INPUT:
*  RMK(J),J=1,2,3=K* THE X,Y,Z COMPONENTS OF THE MATCH POINT.
*  SH(J) J=1,2,3 = THE X,Y,Z COMPOMENTS OF THE UNIT VECTOR POINTING IN
*  THE SAME DIRECTION AS THE SOURCE SEGMENT.
*  RSK(J)= K* THE X,Y,Z COORDINATES OF THE THE SOURCE SEGMENT CENTROID
*  RADSK=K * THE SOURCE SEGMENT RADIUS.
```

```
*  RADSKS=RADSK*RADSK
*  SP IS K* THE DISTANCE ALONG THE SOURCE SEGMENT THAT RPRIME IS FROM
*  THE SOURCE SEGMENT CENTROID. A POSITIVE DISTANCE IS TOWARDS THE
*  ENDPOINT OF THE SOURCE SEGMENT, A NEGATIVE DISTANCE IS TOWARDS THE
*  INITIAL POINT OF THE SOURCE SEGMENT.
* OUTPUT:
*  CKMN=THE REDUCED KERNEL EVALUATED AT R=THE MATCH POINT AND
*  RPRIME(J)=RSK(J)-SP*SH(J).
C-----------------------------------------------------------------------
      DIMENSION RMK(3),SH(3),RSK(3),D(3)
      COMMON/WKERNL/RSK,SH,RMK,RADSK,RADSKS
C
      DO 5 J=1,3
        D(J)=RMK(J)-RSK(J)-SP*SH(J)
 5    CONTINUE
      R=SQRT(D(1)*D(1)+D(2)*D(2)+D(3)*D(3)+RADSKS)
      CKRED=CEXP(CMPLX(0.,-R))/R
      RETURN
      END
```

A.80 ELIC1K

```
C=======================================================================
      FUNCTION ELIC1K(AM1)
C-----------------------------------------------------------------------
* COMPLETE ELLIPITIC INTEGRAL OF THE FIRST KIND K(M), AS DEFINED IN JOHN
*     THE REFERENCE BELOW, WHERE AM1=1-M
*
*          REFERENCE:  HANDBOOK OF MATHEMATICAL FUNCTIONS
*                      ABRAMPWOTZ AND STEGUN
*
*                      EQUATION   17.3.34
C-----------------------------------------------------------------------
      DATA A0,A1,A2,A3,A4,B0,B1,B2,B3,B4/
     >1.38629436112,.09666344259,.03590092383,.03742563713,.01451196212,
     >.500000000000,.12498593597,.06880248576,.03328355346,.00441787012/
C
      IF(AM1 .LT. 1.E-18)THEN
        A=AM1*A1+A0
        B=AM1*B1+B0
      ELSEIF(AM1 .LT. 1.E-12)THEN
        A=AM1*(AM1*A2+A1)+A0
        B=AM1*(AM1*B2+B1)+B0
```

```
ELSEIF(AM1 .LT. 1.E-9)THEN
  A=AM1*(AM1*(AM1*A3+A2)+A1)+A0
  B=AM1*(AM1*(AM1*B3+B2)+B1)+B0
ELSE
  A=AM1*(AM1*(AM1*(AM1*A4+A3)+A2)+A1)+A0
  B=AM1*(AM1*(AM1*(AM1*B4+B3)+B2)+B1)+B0
ENDIF
ELIC1K=A-B*ALOG(AM1)
RETURN
END
```

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